

Development of catalytic asymmetric allylation of dienone

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Boston College

The Graduate School of Arts and Sciences

Chemistry Department

DEVELOPMENT OF CATALYTIC ASYMMETRIC
ALLYLATION OF DIENONE

A thesis

by

LI YAO

Submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

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ABSTRACT

Li Yao

Development of Catalytic Asymmetric Allylation of Dienone

(Under the direction of James P. Morken)

The catalytic allylation of aldehydes, ketones, and imines is a very useful reaction for the formation of a new carbon-carbon bond in synthetic organic chemistry. There have been several successful reports of catalytic asymmetric reactions that use aldehydes as the substrate. However, there have been very few successful examples with ketones. Herein, a nickel-catalyzed allylation of dienones with the pinacol ester of allylboronic acid is presented. Based on 3,3'-reductive elimination, the relationship between the dienone structure and 1,2- and 1,6-regioselectivity has been studied. The development of a catalyzed asymmetric 1,2 allylation of dienones is also presented.

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I thank Dr. James Morken for teaching and training me to be a good researcher in organic chemistry under his advisement. I also thank Dr. Jason Kingsbury and Dr. Lawrence Scott for reading and critiquing this work. I would like to thank the Morken group, especially Joshua Sieber, Heather Burks, Ping Zhang and Hee Yeon Cho for their participation and help in my research and thesis. I also thank Dr. Jason Kingsbury, Dr. Kian Tan and Dr. Marc Snapper for the teaching and help in my organic chemistry study.

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I. Introduction and background

Catalytic asymmetric addition of alkyl or allyl groups to unsaturated substrates is very important for carbon-carbon bond formation. Conjugate addition is one kind of methodology, which is a synthetically important method for the construction of complex organic compounds. In the first chapter, previous research in this area will be reviewed. In subsequent chapters our contribution to this area will be described.

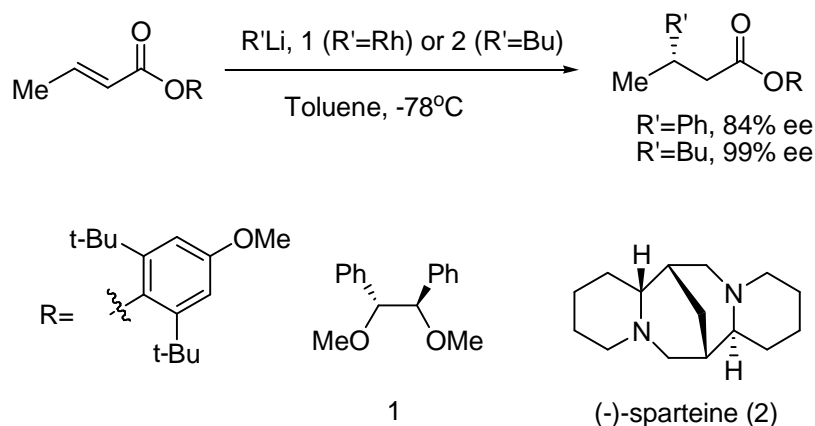
A. Previous research in conjugate addition

There have been several reports on the use of transition-metal catalyst for the conjugate addition of organometallics to activated alkenes. In 1997, the Tomioka group¹ reported that high enantioselectivity in conjugate addition to α,β -unsaturated esters can be achieved by using organolithium reagents in the presence of stoichiometric amounts of chiral ether **1** or amine **2** ligand (Scheme 1). But the requirement of stoichiometric amounts of chiral ligands makes this reaction less enantio-efficient. In order to provide truly efficient strategies, developing catalytic rather than stoichiometric processes becomes the main challenge. In the 1980's, the Lippard group used catalytic amounts of a Cu-amide complex for the conjugate addition; this is the first example.²

¹ Asano, Y.; Iida, A.; Tomioka, K. *Tetrahedron Lett.* **1997**, 38, 8973-8976.

² Villacorta, G. M.; Rao, C. P.; Lippard, S. J. *J. Am. Chem. Soc.* **1988**, 110, 3175-3182.

Scheme 1: Asymmetric conjugate addition of organolithium reagents with stoichiometric chiral ligands



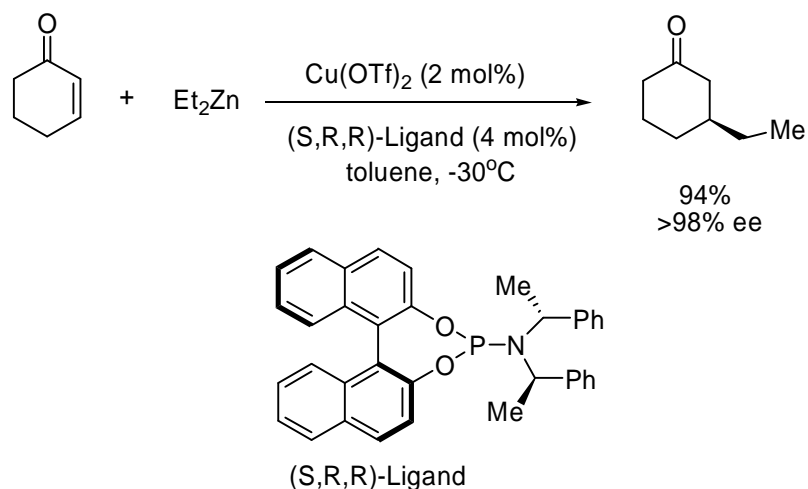
(i) Copper-catalyzed asymmetric conjugate addition of dialkylzinc reagents.

The first highly enantioselective Cu-catalyzed conjugate addition of dialkylzinc reagents to enones was done by the Feringa group³ in 1997, with chiral monodentate phosphoramidites as the ligands. The binaphthol-based phosphoramidite ligand shown in Scheme 2, can improve the enantioselectivity up to 98%. A more recent example was shown by the Leighton group⁴ in 2004. They developed a new P-chiral phosphine bis(sulfonamide) ligand for the Cu-catalyzed enantioselective conjugate addition of diethyl zinc to acyclic aliphatic enones with high enantioselectivity (up to 90-95% ee) (Scheme 3).

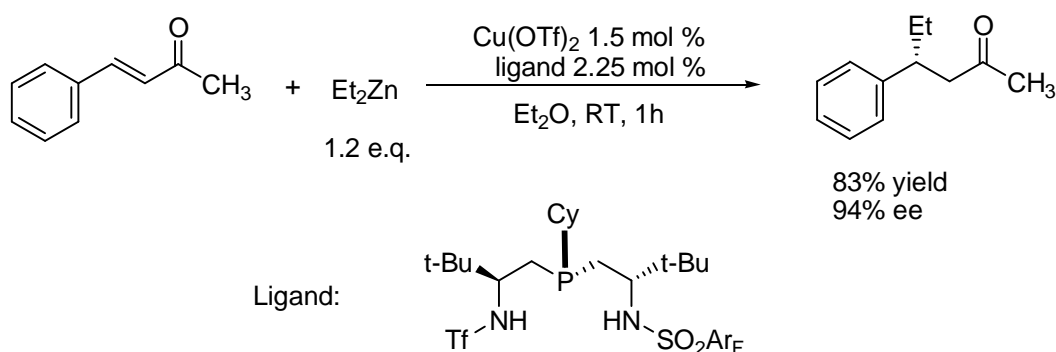
³ Feringa, B.L., Pineschi, M., Arnold, L.A., Imbos, R., de Vries, A. H. M. *Angew. Chem., Int. Ed. Engl.* **1997**, 36, 2620-2623

⁴ Duncan, A. P.; Leighton, J.L. *Org.Lett.* **2004**, 6, 22, 4117-4119

Scheme 2: Cu-catalyzed asymmetric conjugate addition of dialkylzinc reagents to cyclic enones.



Scheme 3: Cu-catalyzed enantioselective conjugate addition of diethyl zinc to acyclic aliphatic enones

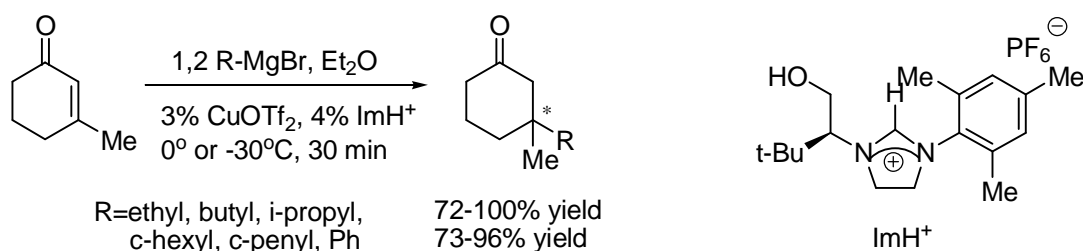


(ii) Catalytic enantioselective conjugate addition of Grignard Reagents.

Dialkylzinc reagents are quite efficient in catalytic enantioselective conjugate addition and they were used instead of Grignard reagents for decades. But, Grignard reagents are readily available, all of the alkyl groups of the organometallic compound are transferable, and the magnesium enolate products are quite useful. However, achieving high enantioselectivity, and avoiding noncatalyzed background reaction, are still two challenging problems when using Grignard reagents.

In 2006, Alexandre Alexakis⁵ reported that combining Grignard reagents and chiral diaminocarbenes can afford enantioenriched all-carbon quaternary centers with the enantioselectivity up to 96% in the copper-catalyzed asymmetric conjugate addition of Grignard reagents to cyclic enones. This method is useful for the addition of the phenyl group to cyclic enones, a reaction that can not be done with other conjugate addition strategies.

Scheme 4: Conjugate addition of Grignard reagents to cyclic enones

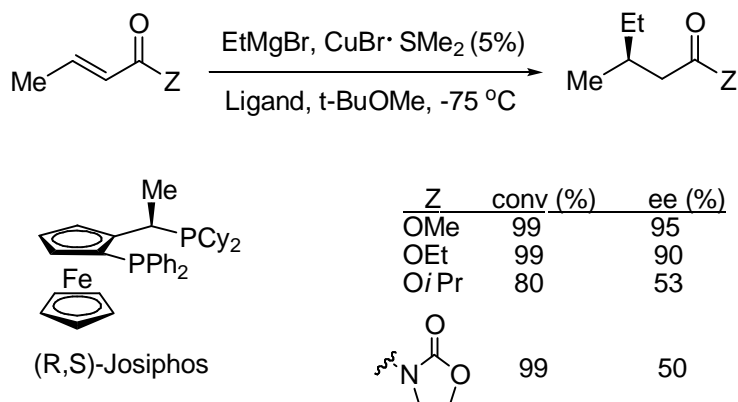


In 2005, the Feringa group⁶ used the Josiphos ligands shown in Scheme 5 to promote the Cu-catalyzed conjugate addition of EtMgBr to simple unsaturated acyclic α,β -unsaturated esters. From the screen in Scheme 5, it can be seen that the esters accommodate any group, such as simple methyl, without the requirement of a sterically hindered substituent to avoid uncatalyzed 1,2-additions.

⁵ Martin, D.; Kehrl, S.; d'Augustin, M.; Clavier, H; Mauduit, M., Alexakis, A. *J. Am. Chem. Soc.* **2006**, 128, 8416-8417

⁶ Lopez F.; Harutyunyan S.R.; Meetsma A.; Minnaard A.J.; Feringa B.L. *Angew. Chem., Int. Ed. Engl.* **2005**, 44, 2752-2856

Scheme 5: Cu-catalyzed conjugate addition of EtMgBr to α,β -unsaturated esters.



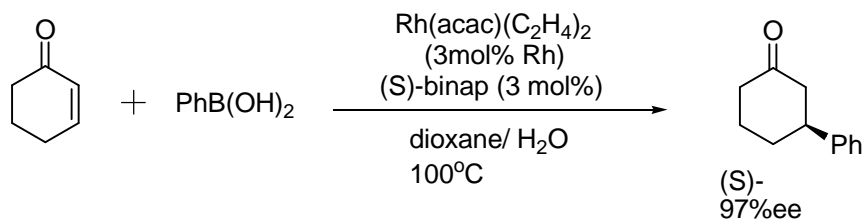
(iii) Rhodium-catalyzed asymmetric conjugate addition.

Rhodium also can be used in the catalyzed asymmetric conjugate addition to give the product with high yield and enantioselectivity. In 1998, Hayashi and Miyaura⁷ reported that the asymmetric conjugate addition of phenylboronic acid to 2-cyclohexenone is effective with high enantioselectivity when using a rhodium complex as the catalyst (Scheme 6). In 2003, Shuichi Oi and Yoshio Inoue⁸ reported that high enantioselectivity can be achieved in conjugate addition of organosiloxanes to α,β -unsaturated carbonyl compounds when catalyzed by a chiral rhodium complex (Scheme 7).

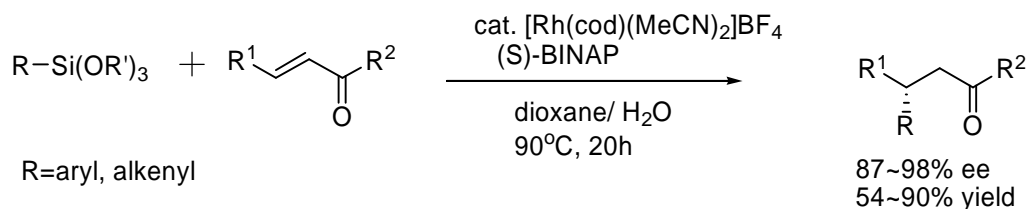
⁷ Takaya, Y.; Ogasawara, M.; Hayashi, T.; Sakai, M.; Miyaura, N. *J. Am. Chem. Soc.* **1998**, 120, 5579.

⁸ Oi, S.; Taira, A.; Honma, Y.; Inoue, Y. *Org. Lett.* **2003**, 5, 97.

Scheme 6: Rhodium-catalyzed asymmetric conjugate addition of aryl- and alkenylboronic acid to enones.



Scheme 7: Asymmetric 1,4-addition catalyzed by a chiral rhodium complex.

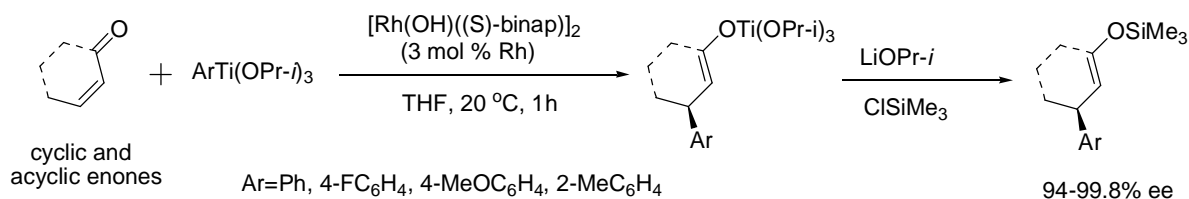


In 2002, Tamio Hayashi⁹ reported using $[\text{Rh(OH)((S)-binap})]_2$ as the catalyst for the conjugate addition of aryltitanium triisopropoxide to unsaturated ketones. This can be achieved with high enantioselectivity to give titanium enolates, which can be converted into silyl enol ethers (Scheme 8). In 2004, Tamio Hayashi¹⁰ used organozinc reagents in the rhodium-catalyzed asymmetric 1,4-addition reaction for the synthesis of 2-aryl-piperidones with high yield and enantioselectivity (Scheme 9).

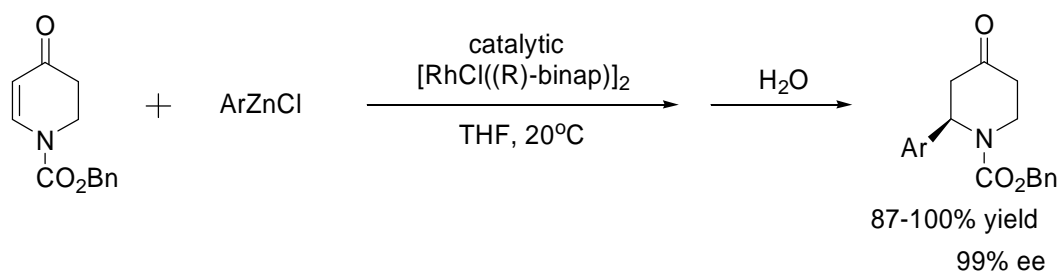
⁹ Hayashi, T.; Tokunga, N.; Yoshida, K.; Han, J. W. *J. Am. Chem. Soc.* **2002**, 124, 12102.

¹⁰ Shintani, R.; Tokunaga, N.; Doi, H.; Hayashi, T. *J. Am. Chem. Soc.* **2004**, 126, 6240.

Scheme 8: Rhodium-catalyzed asymmetric 1,4-addition of aryltitanium reagents.



Scheme 9: Rhodium-catalyzed asymmetric 1,4-addition reaction for the synthesis of 2-aryl-piperidones.



B. Conjugate addition of allyl nucleophiles

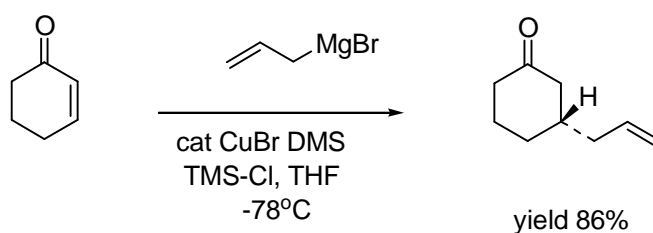
The conjugate addition of allyl nucleophiles to activated alkenes is a synthetically important method because it forms a new carbon-carbon bond and the product contains synthetically useful carbonyl and olefin functional groups.

This well-known process can be achieved by a variety of methods. The first example was reported by Sakurai in 1997¹¹. They used allylsilanes as the reagent and

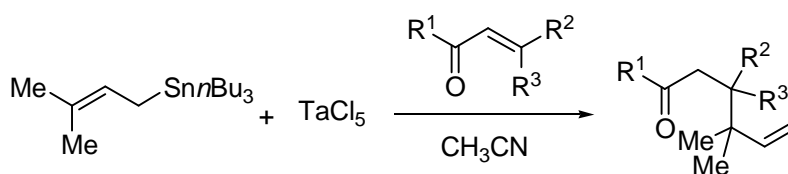
titanium chloride as the Lewis acid to successfully promote the allylation of α,β -enones to give δ,ε -enones.

In 1994, Lipshutz reported that an allylic Grignard, $\text{CuBr} \cdot \text{SMe}_2$, and Me_3SiCl combination with the ratio of 1:1:1 can give 1,4-adducts with high yields, shown as Scheme 10. Shibata and Bada, in 2002, used organotin compound to react with tantalum chloride, through transmetalation, to form an active allyltantalum reagent which can react with α,β -enones to give conjugate adducts in high yield (Scheme 11).¹³

Scheme 10: Allylic copper species used in catalyzed conjugate allylation of enones



Scheme 11: Active allyltantalum reagent used in conjugate allylation of enones.



¹¹ Hosomi, A.; Sakurai, H. *J. Am. Chem. Soc.*, **1977**, 99, 1673.

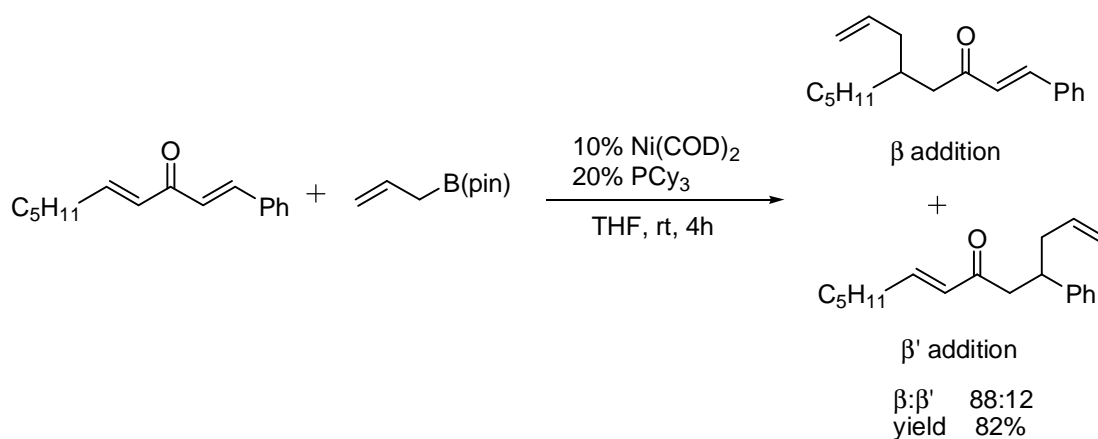
¹² Lipshutz, B. H.; Hackmann, C. *J. Org. Chem.* **1994**, 59, 7437.

¹³ Shibata, I.; Kano, T.; Kanazawa, N.; Fukuoka, S. Baba, A. *Angew. Chem., Int. Ed.* **2002**, 41, 1389.

(i) Conjugate addition to enones bearing an auxiliary unit

As reported by our group in 2007, using Ni and Pd complexes as catalyst, conjugate addition of the allyl group to dialkylidene ketones can be achieved with high yield (Scheme 12)¹⁴. Again, a new stereocenter and a product containing the carbonyl and olefin functional groups formed; this has important synthetic utility.

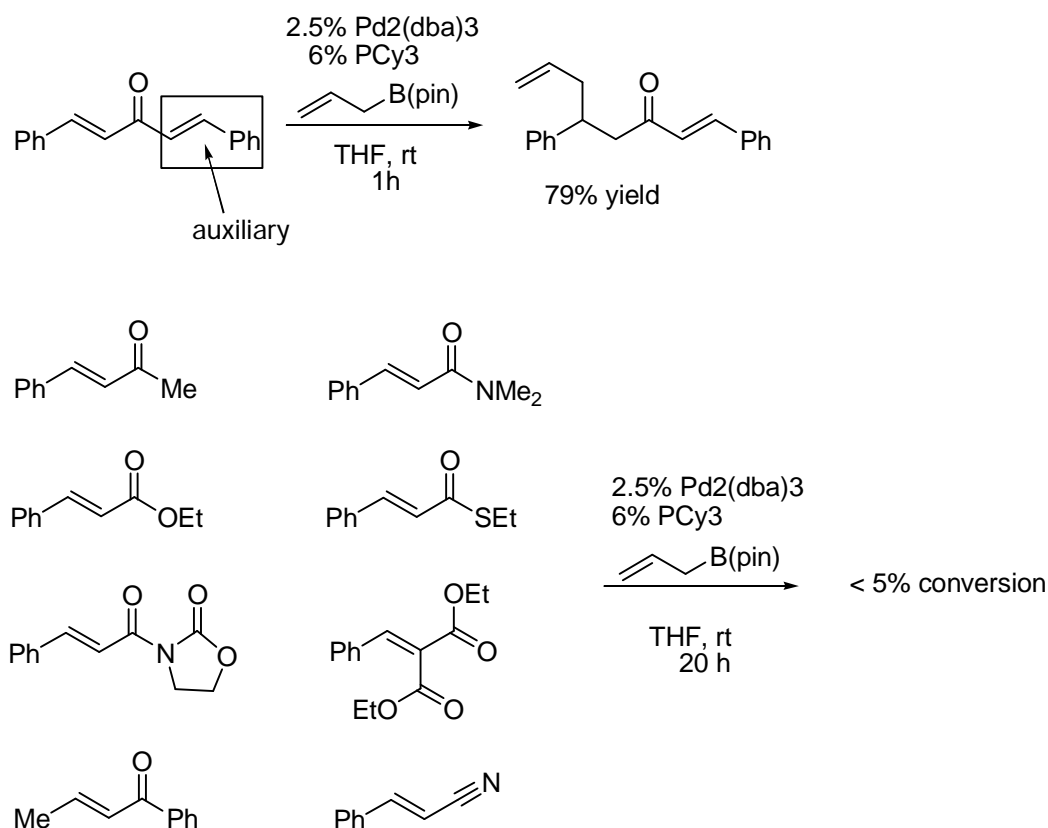
Scheme 12: Catalytic conjugate addition of allyl groups to styryl-activated enones.



While simple enones and their derivatives, such as esters, amides, imides, and nitriles, only give little addition product, the reaction with dialkylidene ketones is quite efficient (Scheme 13), as reported by our group in 2007.¹⁴

¹⁴ Sieber, J.D.; Liu, S.; Morken, J.P. *J. Am. Chem. Soc.* **2007**, 129, 2214-2215.

Scheme 13: The effect of the auxiliary unit in conjugate allylation.



The results shown in Scheme 13 illustrate that an auxiliary alkene unit activates the enone and makes the reaction occur rapidly when an appropriate catalyst is used. Only with both of them, can the reaction happen.

(ii) 3,3'- Reductive elimination.

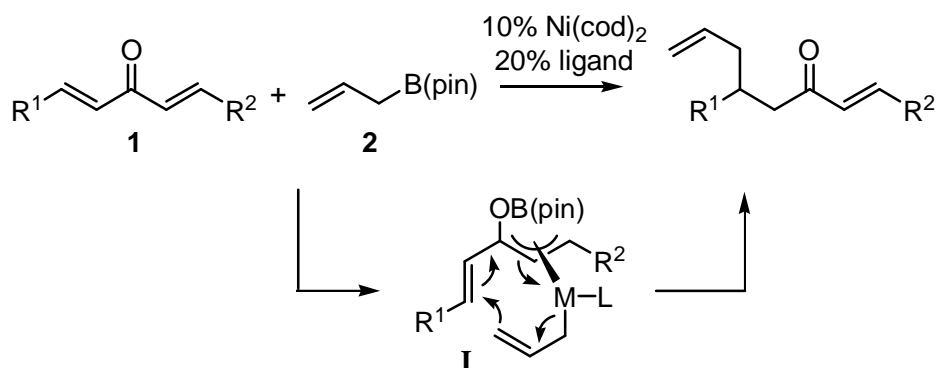
Some studies on the conjugate addition of allyl groups to activated alkenes have already been done and suggest that this kind of reaction proceeds by a mechanism involving 3,3'-reductive elimination^{15,16} from an unsaturated π -allyl complex **I**, after oxidative formation of the derived π -allyl. Computational studies¹⁴ also proved what

¹⁵ Ariafard, A.; Lin, Z. *J. Am. Chem. Soc.* **2006**, 128, 13010

¹⁶ Hirano, K.; Yorimitsu, H.; Oshima, K. *Org. Lett.* **2007**, 1541

has been shown in the Scheme 14.

Scheme 14: The 3,3' reductive elimination mechanism.



C. Research goals.

Like conjugate addition, catalytic allylation of aldehydes, ketones, and imines is also a very useful reaction for the formation of a new carbon-carbon bond in synthetic organic chemistry. There are many successful examples of catalytic asymmetric reactions using aldehydes as the substrates. However, far fewer successful examples are known with ketones, thus revealing the hurdles in chiral tertiary alcohol synthesis.

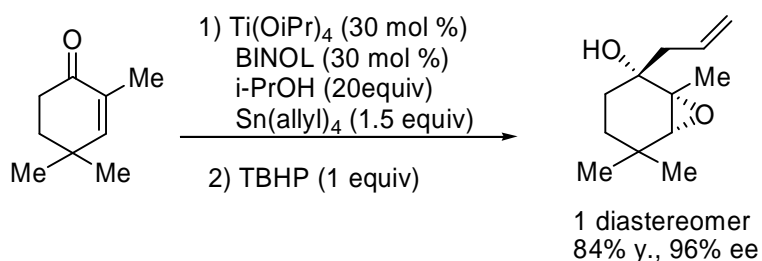
In the light of our success using 3,3' reductive elimination in the conjugate allylation of dialkylidene ketones to give high yield and enantioselectivity, a new substrate, $\alpha,\beta,\gamma,\delta$ -unsaturated ketone, also with an auxiliary unit, was explored to see whether this structure will react.

II. Catalytic asymmetric 1,2-allylation of dienones.

A. Previous research on allylation of carbonyl derivatives.

In 2004, Patrick J. Walsh¹⁷ reported a simple procedure for the catalytic asymmetric allylation of ketones, by using tetraallylstannane as the allylating agent together with titanium tetraisopropoxide, BINOL and 2-propanol as an additive (Scheme 15). A variety of ketone substrates were applied to this reaction with good yields (67-99%) and high enantioselectivity (>80%). A subsequent epoxidation was introduced that occurred with give high diastereoselectivity. Although high enantioselectivity can be achieved in the above example; allylstannanes are somewhat toxic and catalyst loading is as high as 30 mol%. Allylsilanes are generally a more desirable reagent because they are less toxic and more stable than allylstannanes. However, allylsilanes are less reactive than allylstannanes, which limited their synthetic use.

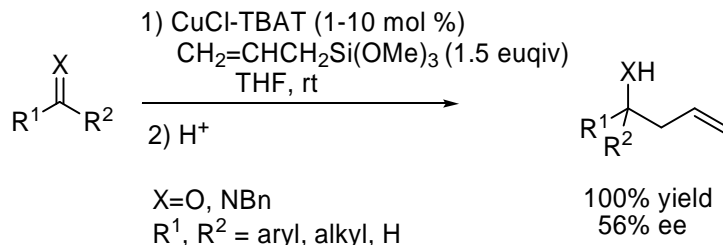
Scheme 15: Catalytic asymmetric 1,2-allylation of ketones by tetraallylstannane.



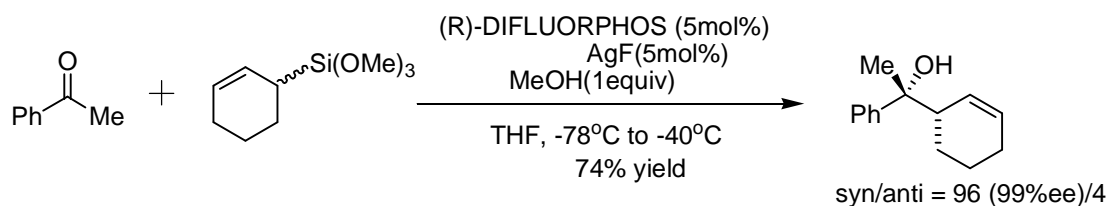
¹⁷ Kim, J.G.; Waltz, K.M.; Garcia, I.F.; Kwiatkowski, D.; Walsh, P.J. *J. Am. Chem. Soc.* **2004**, 126, 12580-12585.

The first catalytic asymmetric allylation with allylsilanes was done in 2002 by the Shibasaki group.¹⁸ They used allyltrimethoxysilane as the allylsilane reagent and 1-10 mol % CuCl and TBAT in THF at room temperature to achieve very high yield and enantioselectivity (up to 60%) (Scheme 16). In 2005, the Yamamoto group¹⁹ further developed this asymmetric Sakurai-Hosomi allylation of simple ketones by using the complex of AgF and (R)-DIFLUORPHOS in THF. With the addition of 1.0 equivalent MeOH and 1:1 complex of AgF and (R)-DIFLUORPHOS, high enantioselectivity (up to 96%) can be achieved; only the 1,2-addition products were observed from conjugate ketones, and high enantioselectivity and diastereoselectivity were common (Scheme 18).

Scheme 16: Catalytic asymmetric 1,2-allylation of ketones by allylsilanes.



Scheme 17: Asymmetric Sakurai-Hosomi allylation of ketones by silver complex.

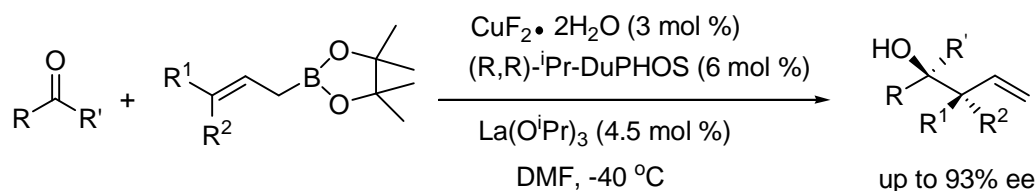


¹⁸ Yamasaki, S.; Fujii, K; Wada, R; Kanai, M; Shibasaki, M. *J. Am. Chem. Soc.*, **2002**, 124, 6536-6537.

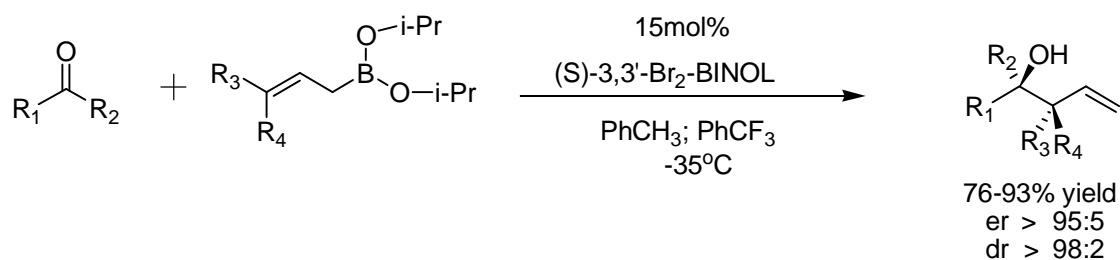
¹⁹ Wadamoto, M.; Yamamoto, H. *J. Am. Chem. Soc.*, **2005**, 127 (42), 14556-14557.

In 2005, the Shibasaki group reported the first catalytic asymmetric allylboration of ketones. They used CuF₂-*i*-Pr-DuPHOS (3 mol %) as a chiral catalyst and La(O*i*Pr)₃ (4.5 mol %) as a cocatalyst to achieve enantioselectivity as high as 93% ee. In 2006, the Schaus group²¹ used chiral diols as catalytic promoters of asymmetric allylboration reactions without using a metal; this is an environmental-friendly, catalytic enantioselective allylboration of ketones. Chiral BINOL-derived diols were used, such as 3,3'-Br₂-BINOL, and allyldiisopropoxyborane was the nucleophile. Good yields (76-93%), high enantioselectivities (er > 98:2), and high diastereoselectivities were obtained (Scheme 19).

Scheme 18: Catalytic asymmetric allylboration of ketone by chiral copper complex.



Scheme 19: Metal-free catalytic enantioselective allylboration by chiral diols.



²⁰ Wada, R.; Oisaki, K.; Kanai, M.; Shibasaki, M. *J. Am. Chem. Soc.* **2004**, 126, 8910 -8911.

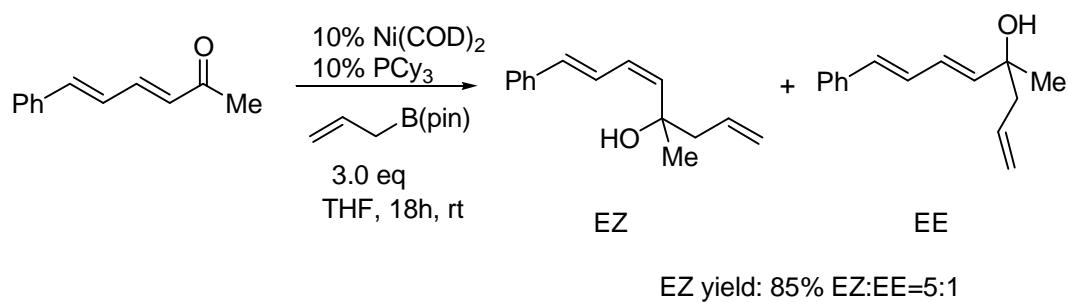
²¹ Lou, S.; Moquist, P. N.; Schaus, S. E. *J. Am. Chem. Soc.* **2006**, 128, 12660.

B. Catalytic allylation of dienones.

In this thesis, the catalytic asymmetric allylation of $\alpha,\beta,\gamma,\delta$ unsaturated ketones, also called dienones, with the pinacol ester of allylboronic acid [allylB(pin)] is described; this reaction is based on the 3,3' reductive elimination that applies to similar unsaturated ketones.

In the presence of $\text{Ni}(\text{cod})_2$ and PCy_3 , an $\alpha,\beta,\gamma,\delta$ -unsaturated carbonyl electrophile, with an aromatic ring in the alkene side reacted by carbonyl addition as the predominant reaction pathway (Scheme 20).

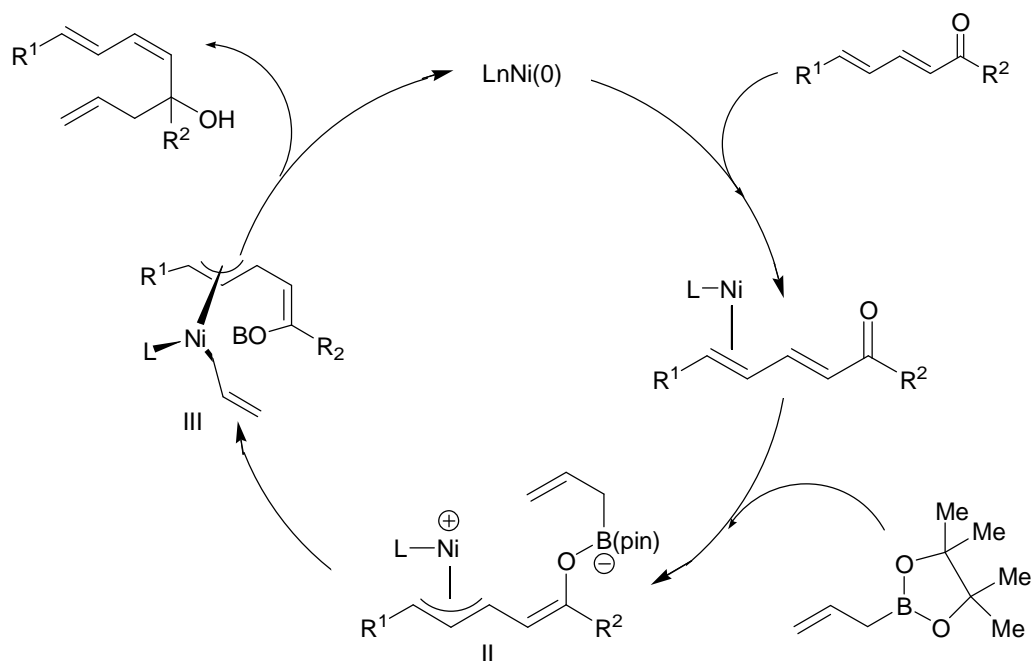
Scheme 20: Nickel-catalyzed allylation of dienones.



(i) Proposed mechanism

The proposed catalytic cycle for this reaction is shown in Scheme 21. We can see that this reaction cycle began with a boron-activated oxidative addition of an enone to a nickel catalyst to form the π -allyl complex II (Scheme 20), and then transmetalation gave the π -allyl complex III. After that, 3,3'-reductive elimination generated the 1,2-allylation product and gave the nickel(0) back.

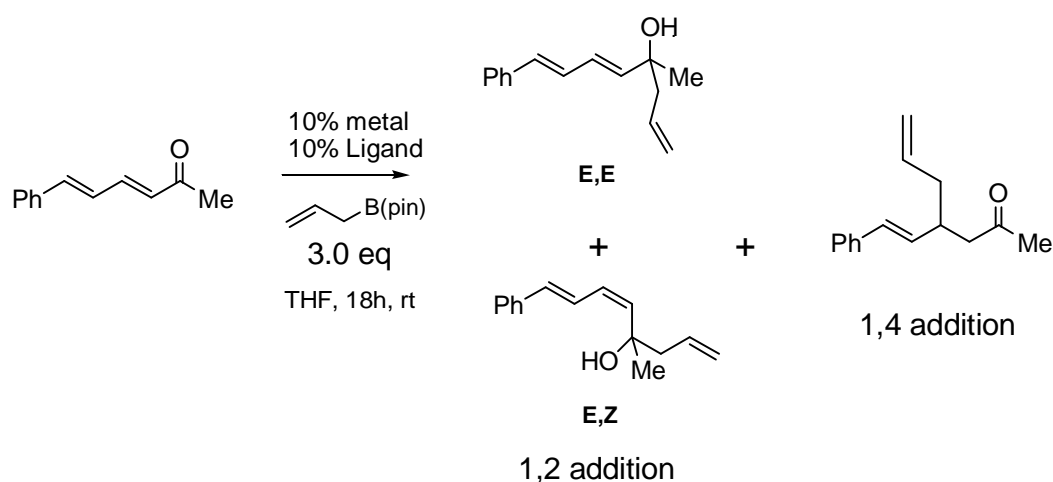
Scheme 21: Proposed catalytic cycle for the Ni-catalyzed 1,2-allylation of dienones



(ii) Development of a catalyzed 1,2-allylation of dienones.

In order to make this conjugate allylation useful in broad synthesis settings, it requires an efficient reaction which should have both high yield and high chemo/stereo-selectivity. Thus, we choose (3E, 5E)-6-phenylhexa-3, 5-dien-2-one as a substrate to screen a variety of achiral phosphorous ligands and metals, as shown in Table 1.

Table 1: Catalyst survey in Ni-catalyzed 1,2-allylation of dienone



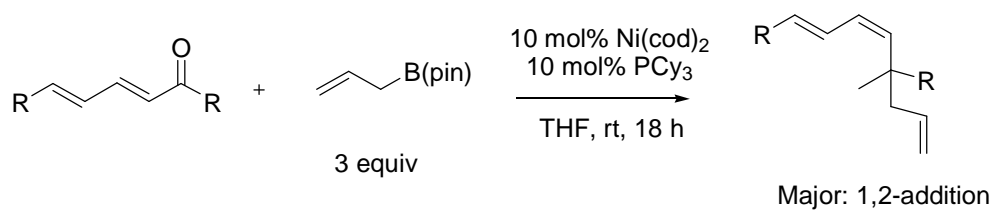
Entry	Metal	Ligand	% (1,2) [EE:EZ]	% (1,4)
1	Ni(COD) ₂	PPh ₃	62 (10: 1)	10
2	Ni(COD) ₂	PCy ₃	84 (1:10)	< 5
3	Ni(COD) ₂	P(NMe ₂) ₃	80 (1: 1)	< 5
4	Ni(COD) ₂	P(OEt) ₃	44 (>50:1)	38
5	Pd ₂ (dba) ₃	PCy ₃	30 (1: 1)	< 5
6	Pd ₂ (dba) ₂	PPh ₃	< 5	< 5

The result of this screen showed that catalysis with nickel was more effective than with palladium (entry 5 and entry 6). Also, the reaction with PCy₃ was much more effective than with other phosphorous ligands. Clearly, the reaction with nickel and PCy₃ (entry 2) is the best compared to the other conditions.

C. Application of the Ni-catalyzed 1,2-allylation of dienones to other substrates.

A number of this kind of dienone, with the aromatic ring attached to the δ carbon participate into this 1,2-allylation (Table 2). Surveying substrates shows the relationship between product yields and dienone structure. From the results, it is postulated that with the aromatic ring at the δ carbon, the major products will always be the 1,2 adducts. The size of the group adjacent to the carbonyl group also affects the yield of 1,2-allylation product. But all of the substrates with alkyl ketone can achieve yields around 60~95%.

Table 2: Ni-catalyzed allylation of different substrates to give 1,2 adducts



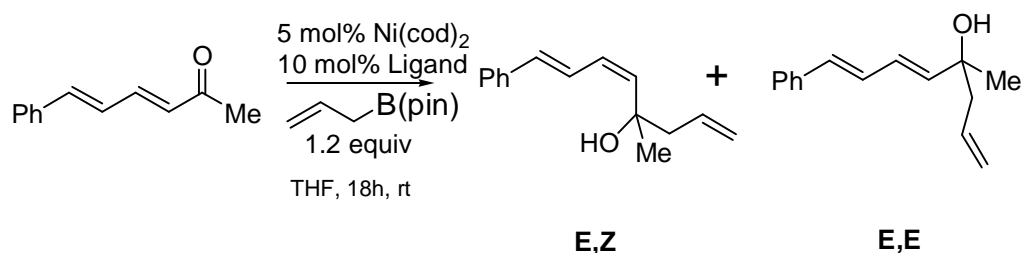
entry	reactant	Major product	Yield (%)
1			70
2			95
3.			55
4			79
5			90
6			94

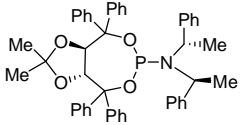
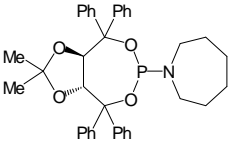
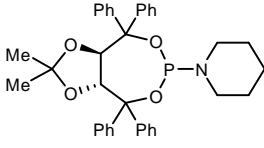
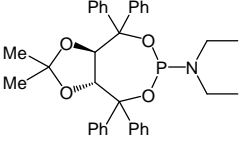
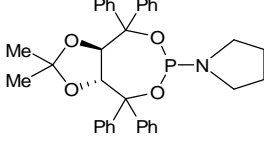
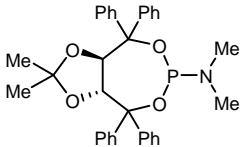
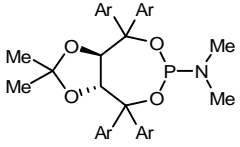
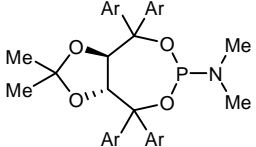
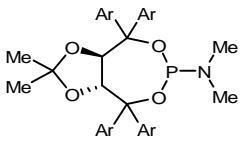
D. Ni-catalyzed asymmetric allylation of activated enones.

With the goal of developing a general catalytic enantioselective allylation of ketones, a collection of chiral phosphorous ligands was surveyed in the 1,2-allylation reaction. TADDOL-derived phosphoramidites, phosphonites, and phosphites were initially explored. The results of some of the TADDOL-derived ligands are shown in Table 3.

Most of these phosphoramidites employed gave good yields, indicating that these ligands are acceptable in the reaction. A decrease in the size of the amino group in the ligands are acceptable in the reaction. A decrease in the size of the amino group in the ligand appears to lower the enantioselectivity (entries 2-6, Table 3). However, enlarging the TADDOL-backbone by substituting the phenyl group with 3,5-dimethylphenyl groups and 3,5-diisopropylphenyl group led to a reduction in ee (entry 7 and 8) while substituting with 3,5-di-*t*-butyl groups led to an inversion in ee -73% (entry 9). It is possible that the larger the amino-group and the smaller the aryl group or the smaller the amino-group and the larger the aryl group, the higher enantioselectivity can be attained. From all of these data, it is easy to see that entry 2, entry 3, and entry 9 give the best enantioselectivity, E,Z selectivity, and also good yield.

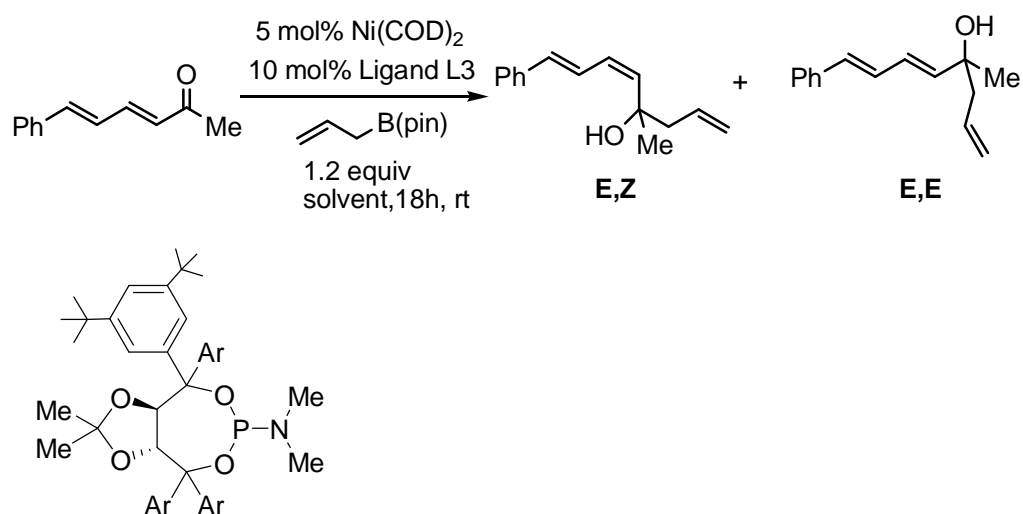
Table 3: Ligand screen in the catalytic asymmetric allylation of ketone



entry	ligand	Yield (%)	EZ:EE	ee (%)
1		0	n/a	n/a
2		84	6:1	74
3		50	3.7:1	72
4		38	8:1	52
5		73	19:1	27
6		34	13:2	26
7	 Ar = 3,5-di-methyl	30	14:1	26
8	 Ar = 3-isopropylphenyl	77	n/a	17
9	 Ar = 3,5-di- <i>t</i> -butylphenyl	58	14:1	-73

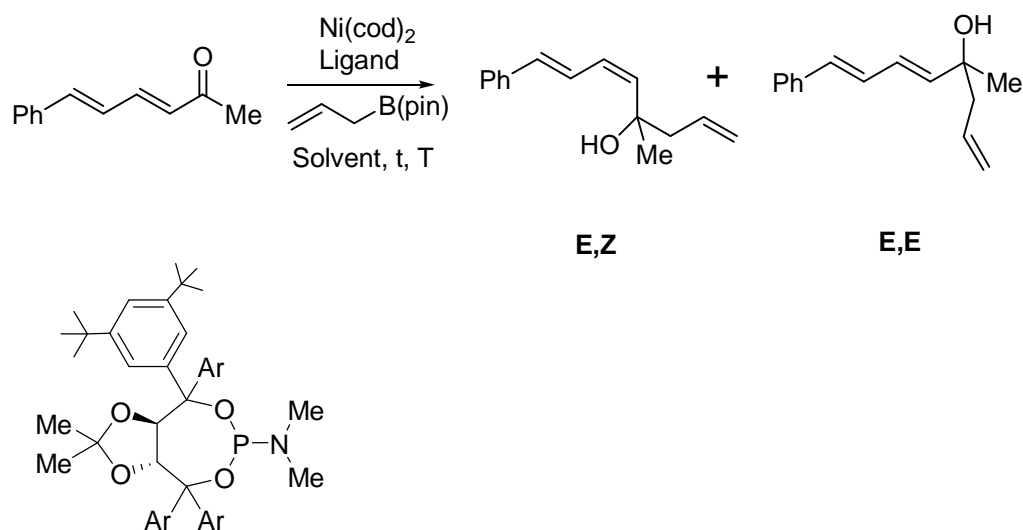
E. Development of an asymmetric catalytic 1,2-allylation of Dienones.

In order to optimize the yield and enantioselectivity, we chose the TADDOL-derivative from entry 9 in Table 3 as the ligand and screened different solvents (Table 4). From entry 2, entry 3, and entry 4, we can see that using ethyl ether as the solvent can not only increase the yield up to 83% but also increase the EZ selectivity, as high as 43:1; THF and toluene can greatly increase the enantioselectivity up to around 75%, but no reaction occurred in CH₃CN (entry 1). Thus, we chose THF and ethyl ether as the solvent to optimize other conditions.

Table 4: Solvent effect on the asymmetric Ni-catalyzed 1,2-allylation of dienones

Entry	Solvent	Yield (%)	EZ: EE	ee (%) of EZ
1	CH ₃ CN	0	n/a	n/a
2	THF	58	14:1	-73
3	Ethyl Ether	83	43:1	-57
4	Toluene	56	17:1	-74

The reaction temperature also affects the result substantially. From Table 5, at temperatures below -76°C conversion is very low, while at -20°C enantioselectivity increases a bit but the yield also decreased. While at 0°C and with THF solvent, -80% ee can be attained and the yield is as high as 47% (entry 6).

Table 5: Other effects on the asymmetric Ni-catalyzed 1,2-allylation of dienone

entry	AllylB(pin)	Metal (mol%)	Ligand	Solvent	t (h)	T (°C)	Yield (%)	EZ/EE	ee (%) of EZ
1	1.2	5	10	ethyl ether	18	rt	83	43:1	-57
2	1.2	5	10	ethyl ether	18	-78	0	n/a	n/a
3	1.2	5	10	ethyl ether	18	-20	12	>50:1	-76
4	1.2	5	10	THF	18	rt	58	14:1	-73
5	1.2	5	10	THF	18	-20	10	7:1	-82
6	1.2	5	10	THF	18	0	47	>50:1	-80
7	3.0	10	10	THF	18	rt	96	>>50:1	-70
8	3.0	10	10	THF	42	10	85	>50:1	-71

When the amount of metal was increased up to 10%, and the amount of allyl-B(pin) was increased up to 3.0 equivalents (entry 7), the yield improved dramatically while the enantioselectivity was not affected. But at the lower temperature of 10°C (entry 8), the yield decreased while the enantioselectivity did not

increase much. Thus, we chose the condition shown in entry 7 as the general condition for further study.

F. Application of the asymmetric catalytic 1,2-allylation of dienones to different substrates

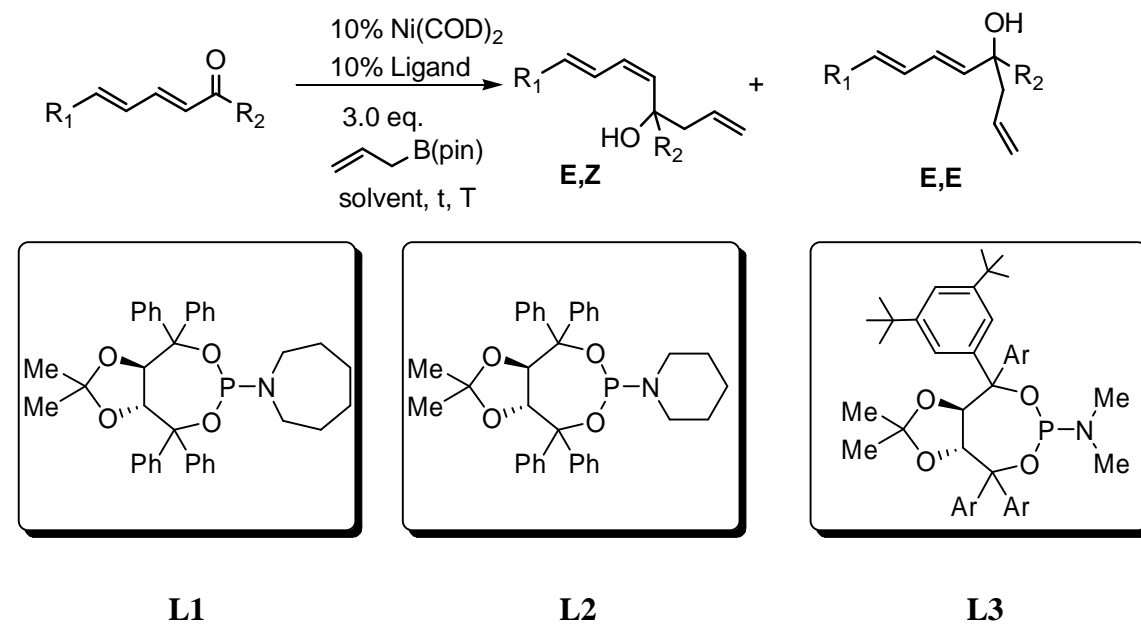
A number of dienones with an aromatic ring at the δ carbon were examined with chiral ligands in this asymmetric 1,2-allylation. As we can see from Table 3, an increase in the size of the amino group on the ligand appeared to increase the enantioselectivity, so two ligands (entry 2 and entry 3, table 3) were examined with each substrate (Table 6). Generally, the ligand with a 3,5-di-*t*-butyl phenyl ring on the TADDOL backbone led to an inverse enantioselectivity (entry 9, table 3), so this ligand was also tried in the substrate study.

For the methyl ketone substrate, the yield was 84%, 65% and 96% when using L1, L2 and L3 as the ligand respectively (entries 1-3), while the ee ranged around 74% (entry 1), 70% (entry 2) and -70% (entry 3). For the phenyl ketone substrate, the ee increased up to 93% (entry 4) and 88% (entry 5) for L1 and L2, while it decreased down to -54% for L3 (entry 6). However, the yield with all three ligands decreased relative to the reaction with the methyl ketone. For the substrate with isopropyl group as R_2 , the ee is 87% (entry 7), 81% (entry 8) and -73% (entry 9).

Generally, ligand 1 with the seven membered azacycle gives the best enantioselectivity, while ligand 3 with 3,5-di-*t*-butyl aromatic ring on the TADDOL backbone gives the highest yield. The reaction of the substrate with a phenyl group

can achieve the enantioselectivity above 90%, while the yield is just around 50%.

Table 6: Substrate scope in a Ni-catalytic asymmetric 1,2 allylation of dienones



Entry	R ₁	R ₂	Ligand	Yield (%)	EZ: EE	ee (%) of EZ
1	Ph	Me	L1	84	6:1	74
2	Ph	Me	L2	65	6:1	70
3	Ph	Me	L3	96	>50:1	-70
4	Ph	Ph	L1	40	3:1	92
5	Ph	Ph	L2	41	3:1	88
6	Ph	Ph	L3	69	2:1	-54
7	Ph	Isopropyl	L1	67	2:1	87
8	Ph	Isopropyl	L2	55	>20:1	81
9	Ph	Isopropyl	L3	76	6:1	-73

III. Catalytic enantioselective 1,6-conjugate allylation of dienones.

A. Previous research on catalytic 1,6-conjugate addition.

Much progress has been made on catalytic asymmetric 1,4- and 1,2-addition to unsaturated carbonyl derivatives as described in Chapter I of this account. However, asymmetric 1,6-addition to conjugated systems has not been well-developed. At the beginning of this chapter, let us first examine what has already been achieved in the area of 1,6-conjugate addition.

(i). Metal-catalytic 1,6-conjugate addition reaction

Copper salts are an excellent catalyst for conjugate addition of Grignard reagents to unsaturated carbonyl compounds^{22, 23, 24} and there are also several examples of 1,6-addition of organocopper reagents to $\alpha,\beta,\gamma,\delta$ -unsaturated carbonyl derivatives. However, 1,6 conjugate addition of aryl Grignard reagents to some 2,4-dienoates using copper catalysis faces some difficulty.

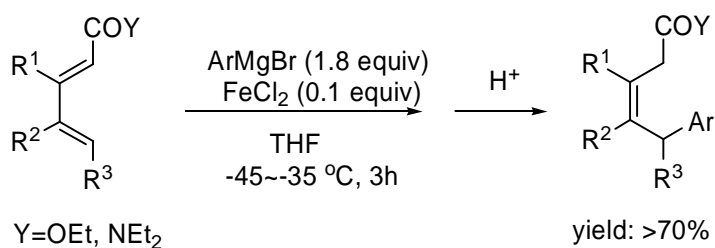
²² Corey, E. J.; Kim, C. U.; Chen, R. H. K.; Takeda, M. *J. Am. Chem. Soc.* 1972, 94, 4395–4396;
Corey, E. J.; Boaz, N. W. *Tetrahedron Lett.* **1985**, 26, 6019–6022.

²³ Modi, S. P.; Gardner, J. O.; Milowsky, A.; Wierzba, M.; Forgione, L.; Mazur, P.; Solo, A. J.;
Duax, W. L.; Galdecki, Z.; Grochulski, P.; Wawrzak, Z. *J. Org. Chem.* **1989**, 54, 2317–2321

²⁴ Krause, N.; Gerold, A. *Angew. Chem., Int. Ed.* **1997**, 36, 186–204.

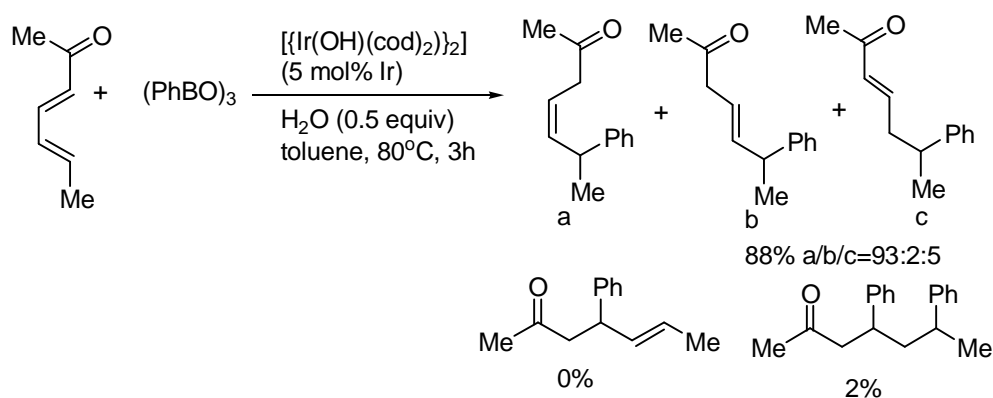
In 2005, Urabe²⁵ reported an alternative way to give high 1,6 regioselectivity by using iron salts to replace copper reagents as the catalyst, shown by Scheme 22.

Scheme 22: Iron-catalyzed 1,6-conjugate addition to dienoates.



Instead of using an iron complex as the catalyst, perfect 1,6-selective addition of aryl boronic acids to electron-deficient dienones can also be achieved, by using an iridium complex $[\{\text{Ir}(\text{OH})(\text{cod})\}_2]$ as the catalyst.²⁶

Scheme 23: $[\{\text{Ir}(\text{OH})(\text{cod})\}_2]$ complex in 1,6 addition of dienones.



²⁵ Fukuhara K.; Urabe H. *Tetrahedron Lett.* **2005**, 46, 603-606

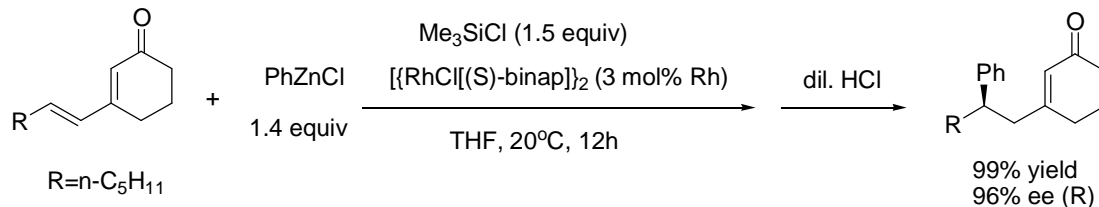
²⁶ Nishimura, T.; Yasuhara, Y; Hayashi, T. *Angew. Chem. Int. Ed.* **2006**, 45, 5164-5166

(ii). Catalyzed enantioselective 1,6-conjugate addition reaction

Like what has been shown above, several methodologies have been reported for 1,6-additions, however, catalyzed asymmetric transformations still have not been greatly developed. Recently, there have been two reports in this area.

The first example of a catalytic enantioselective 1,6-addition was reported by Hayashi in 2005 (Scheme 24).²⁷ They used chlorotrimethylsilane as a Lewis acid and a rhodium/(S)-binap complex as the catalyst to achieve high enantioselectivity in the preparation of α,β -unsaturated ketones with a new stereogenic center; high yield (99%) and high enantioselectivity (96% ee) was observed.

Scheme 24: First catalytic asymmetric 1,6-addition

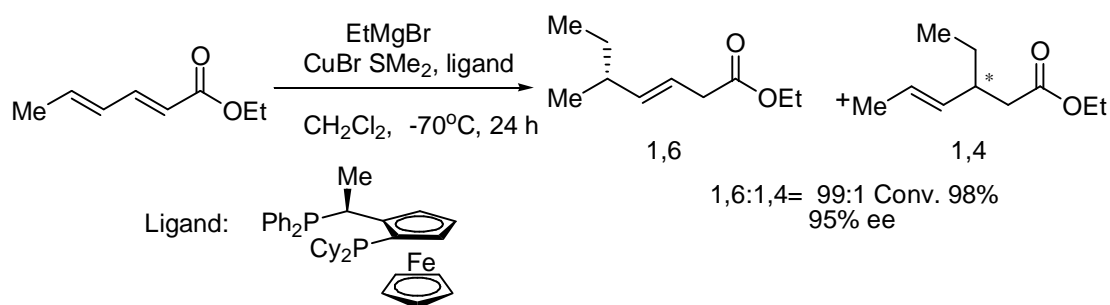


Then, the Feringa group²⁸ reported the first Cu-catalyzed enantioselective conjugate addition of simple alkyl Grignard reagents to linear δ -substituted 2,4-dienoates. The β,γ -unsaturated 1,6-addition product could be obtained with excellent regio- and enantioselectivity by employing the reversed josiphos ligand (Scheme 25) at -70°C.

²⁷ Hayashi T; Yamamoto, S; Tokunaga, N. *Angew. Chem. Int. Ed.* **2005**, 44, 4224-4227

²⁸ den Hartog, T; Harutyunyan, S.R.; Font D.; Minnaard, A.J.; Feringa, B.L. *Angew. Chem. Int. Ed.* **2008**, 47, 398-401

Scheme 25: First Cu-catalyzed enantioselective conjugate addition to linear δ -substituted 2,4-dienoates

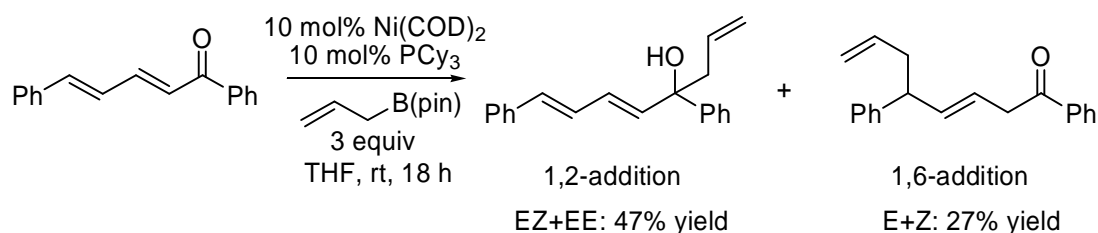


In the few examples above, the excellent regioselectivity is limited to specific structural features in the substrates. Also, 1,6-conjugate allylation of dienones have not been developed. Thus, there is a promising pathway ahead to encourage us to continue in this area.

B. Discovery of 1,6-allylation during 1,2-allylation of dienones

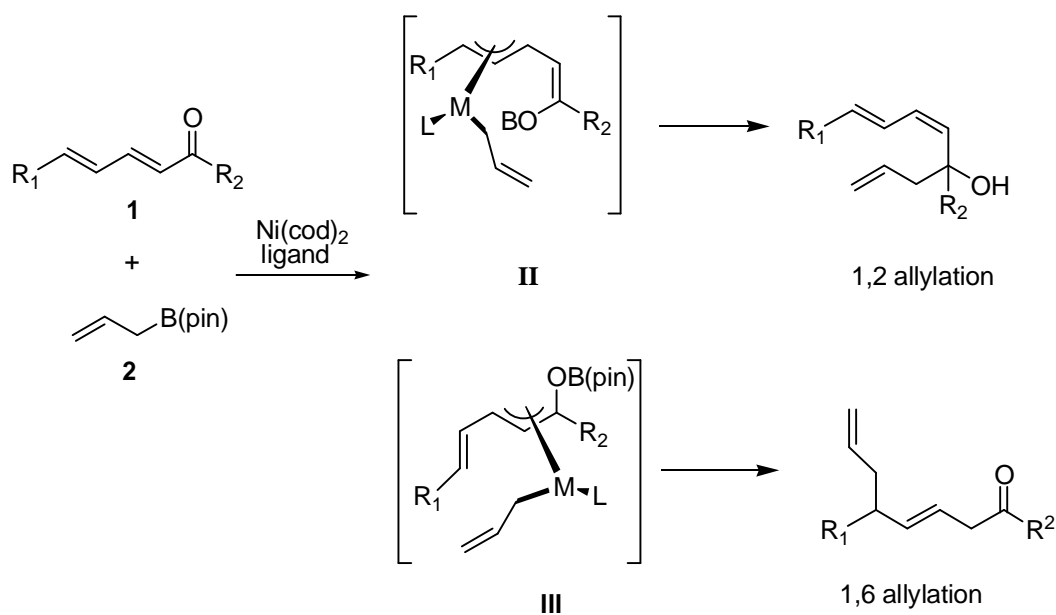
Returning to what has been discovered at the end of Chapter II, the phenyl ketone substitute reacted with the yield around 50% for the 1,2-allylation of dienone. Then, what was the other 50% of the product? The by-product is the 1,6 conjugate addition product, as shown in the Scheme 26 below.

Scheme 26: Allylation adducts for (2E,4E)-1,5-diphenylpenta-2,4-dien-1-one



Our original hypothesis about how the 1,6-conjugate addition occurs is shown below (Scheme 27), and is based on the mechanistic studies previously done in our lab.

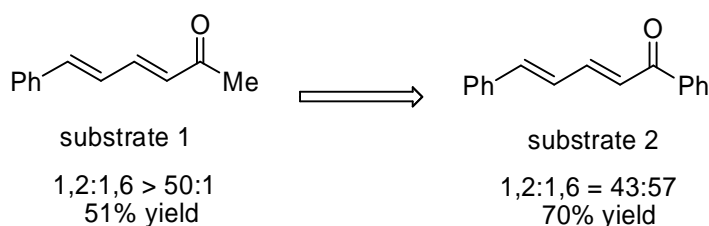
Scheme 27: Proposed mechanism for the formation of 1,2 and 1,6 adducts



From the above scheme, it is easy to see how the 1,6-conjugate addition product is generated. It appears that this reaction may also proceed through 3, 3' reductive elimination. As shown in Scheme 6, the 1,2- and 1,6- allylation products arise from different intermediate bis(allyl) complexes, II or III, respectively.

As observed from the differences between substrates 1 and 2 (Scheme 28), a phenyl ketone is employed, the ratio of 1,6-addition product is much higher than when the methyl ketone is used. The reason is probably that when R_2 is an aromatic ring, the complex III is much more stable, giving more 1,6-addition product. Similar to conjugate addition of allyl groups to dialkylidene ketones, the allyl group tended to transfer distal to aromatic ring substituent.

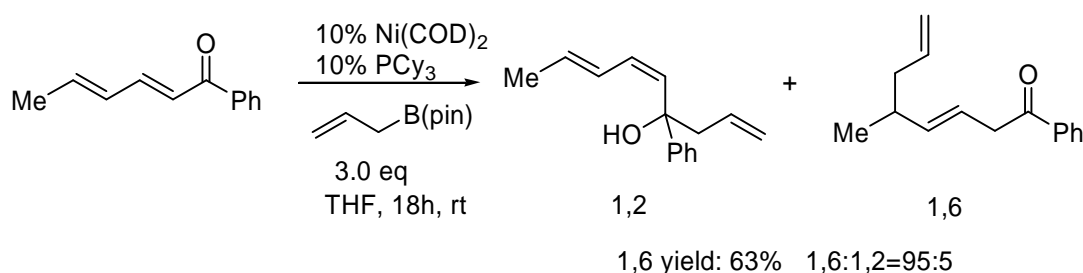
Scheme 28: Difference in the products of two substrates



In order to improve the regioselectivity of 1,6 addition reaction, it will be good to make complex III much more stable than complex II. Thus, the substrate with an aliphatic group as 2 and phenyl group as R₂ would be a promising substrate to give a high ratio of 1,6 addition product.

As we expected, the major product of nickel-catalyzed allylation of (2E,4E)-1-phenylhexa-2,4-dien-1-one was the 1,6-adduct, with the yield as high as 63% and 1,6:1,2 ratio up to 95:5 (Scheme 29).

Scheme 29: Nickel catalyzed allylation of (2E,4E)-1-phenylhexa-2,4-dien-1-one



C. Substrate scope in 1,6-allylation of dienones.

A number of dienones with an aromatic ketone and the alkyl group on the δ carbon participate into this nickel catalyzed allylation (Table 2). This structure ensures that high selectivity for 1,6 addition occurs during the allylation reaction.

Table 7: Ni-catalyzed conjugate allylation of different substrates to give 1,6 adducts

Entry	Substrate	Major product	Yield
1			63
2			55
3			74
4			33

D. Conclusions

In conclusion, we have discovered a nickel-catalyzed allylation of dienones with the pinacol ester of allylboronic acid. The reaction proceeds through a $\eta^3 \pi$ -allyl complex intermediate, which undergoes 3,3'-reductive elimination. We also studied the relationship between the dienone structure and 1,2- and 1,6-regioselectivity. We developed the 1,2- and 1,6-allylation to give high yield by using 3.0 equivalent allylB(pin) and 10 mol % of the catalyst complex. By screening different chiral ligands, we also developed the catalyzed asymmetric 1,2 allylation of dienones with high enantioselectivity.

IV. Experimental section:

General: ^1H NMR spectra were recorded on Gemini-400 (400 MHz) spectrometers. Chemical shifts are reported in ppm from tetramethylsilane with the solvent resonance as an internal standard (CDCl_3 : 7.26 ppm). Data are reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), and coupling constants (Hz). ^{13}C NMR was recorded on a Gemini-400 (100 MHz) instrument, or a Gemini-500 (125 MHz) instrument with complete proton decoupling. Chemical shifts are reported in ppm from tetramethylsilane with the solvent as the internal standard (CDCl_3 : 77.2 ppm). Infrared (IR) spectra were recorded on a Nicolet 210. Low-resolution mass spectrometry was obtained by the Boston College, Department of Chemistry Mass Spectrometry Facility.

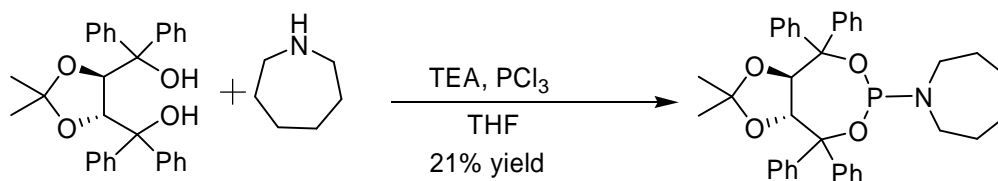
Liquid chromatography was performed using forced flow (flash chromatography) on silica gel (SiO_2 , 40-63 μm) purchased from Silicycle. Thin layer chromatography (TLC) was performed on 250 μm silica gel plates from Silicycle. Visualization was obtained by using UV light, phosphomolybdic acid in ethanol, or potassium permanganate in water, and then followed by heating.

Analytical chiral gas-liquid chromatography (GLC) was performed on a Hewlett-Packard 6890 series chromatograph equipped with a CTC Analysis Combi Pal autosampler by Leap Technologies (Carrboro, NC), a split mode capillary injection system, a flame ionization detector, and a Supelco β -dex 120 column with

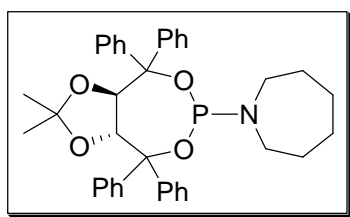
helium as the carrier gas. Analytical achiral GLC was performed on a Hewlett-Packard 6890 series chromatograph equipped with a split mode capillary injection system, a flame ionization detector, and a Hewlett-Packard Ultra 1 capillary column (0.33 μ m film thickness, 25 m length, 0.2mm ID) with helium as the carrier gas. Analytical chiral supercritical fluid chromatography (SFC) was performed on a Berger Instruments supercritical chromatograph equipped with an Alcott autosampler and a Knauer UV detector.

All reactions were conducted in oven or flame dried glassware under an inert atmosphere of nitrogen or argon. Toluene, d₈-toluene, and d₆-benzene were distilled over CaH₂ and degassed by freeze-pump-thaw cycles prior to use. Anhydrous tetrahydrofuran (THF), methylene chloride, and diethyl ether were purified using a Pure Solv MD-4 solvent purification system from Innovative Technology Inc. by passing the solvent through two activated alumina columns after being purged with Ar. Activated dienone substrates used in the 1,2-allylation were synthesized by the Wittig reaction and that used in 1,6-allylation were synthesized by the desired Grignard reagent to the corresponding aldehyde. Bis(1,5-cyclooctadiene)nickel(0) was purchased from Strem Chemical Company. 5-fluoro-2-methylbenzaldehyde was purchased from Oakwood Chemicals and used without further purification. All other reagents were purchased from either Fisher or Aldrich Chemical Companies and used directly.

Ligand Synthesis:



2.41 ml (21.4 mmol) of hexamethyleneimine was added to a mixture of 1.0 g (2.14 mmol) of diol (synthesized from L-tartaric acid)²⁹ and 4 Å molecular sieves in 20.0 mL of THF at 0 °C. The solution was warmed up to ambient temperature for 30 minutes. Next, 0.22 ml (2.57 mmol) of trichlorophosphine was added to the mixture dropwise. The reaction was warmed up to room temperature and kept stirring there for overnight. Et₂O was used to dilute the reaction, and then celite was used to filter the solution. The filtration was concentrated under reduced pressure. Column chromatography (SiO₂, hexanes:EtOAc) gave 0.27 g (21%) of phosphonite ligand as a white solid.



1-((3aR,8aR)-2,2-dimethyl-4,4,8,8-tetraphenyl-tetrahydro-[1,3]dioxolo[4,5-*e*][1,3,2]dioxaphosphepin-6-yl)azepane. ¹H NMR (400 MHz, CDCl₃): δ 7.81-7.79 (2H,

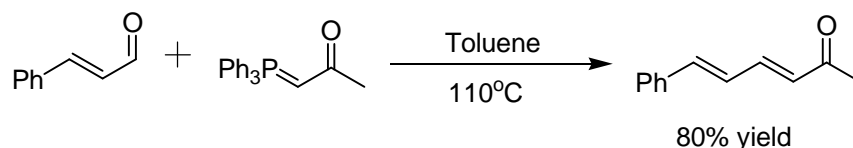
m), 7.65-7.62 (2H, m), 7.49-7.43 (4H, m), 7.34-7.17 (12H, m), 5.21-5.18 (1H, dd, *J*=3.6, 8.4 Hz), 4.78-4.75 (1H, d, *J*=8.8 Hz), 3.40-3.23 (4H, m), 1.74-1.65 (8H, m), 1.35 (3H, s), 1.27 (3H, s); 147.41 146.87 142.62 142.12 129.27 128.96 128.17 127.76 127.65 127.53 127.44 127.35 127.26 127.16 127.12 111.62 82.87 82.64 82.44 81.68

²⁹ Seebach, D.; Beck, A. K.; Keckel, A. *Angew. Chem. Int. Ed.* **2001**, 40, 92.

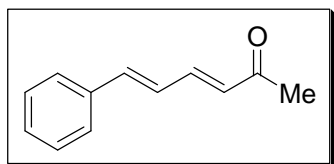
81.50 81.40 (the region 81.40-82.87 ppm contains extra carbon peaks, due to C-P Coupling, see: Boele, M.D.K.; Kamer, P.C.J.; Lutz, M.; Spek, A.L.; de Vries, J.G.; van Leeuwen, P.W.N.M.; van Strijdonck, G.P.F. *Chem. Eur. J.* **2004**, *10*, 6232) 47.10 31.54 30.37 27.87 25.54; ³¹P NMR (300 MHz, CDCl₃): 141.7; IR (CH₂Cl₂): 3063 (w), 2994 (w), 2926 (m), 2854 (w), 1492 (m), 1446 (m), 1372 (m), 1250 (m), 1214 (m), 1163 (m), 1083 (m), 1032 (s), 999 (m), 937 (w), 907 (w), 876 (s), 824 (m), 801 (m), 773 (m), 738 (s), 700 (s), 662 (w), 638 (w), 534 (m) cm⁻¹; LRMS (ESI+) Calc'd for C₃₇H₄₁NO₄P (M+H)⁺: 594.27732 Observed (M+H)⁺: 594.41776.



Representative procedure for the synthesis of dienones:



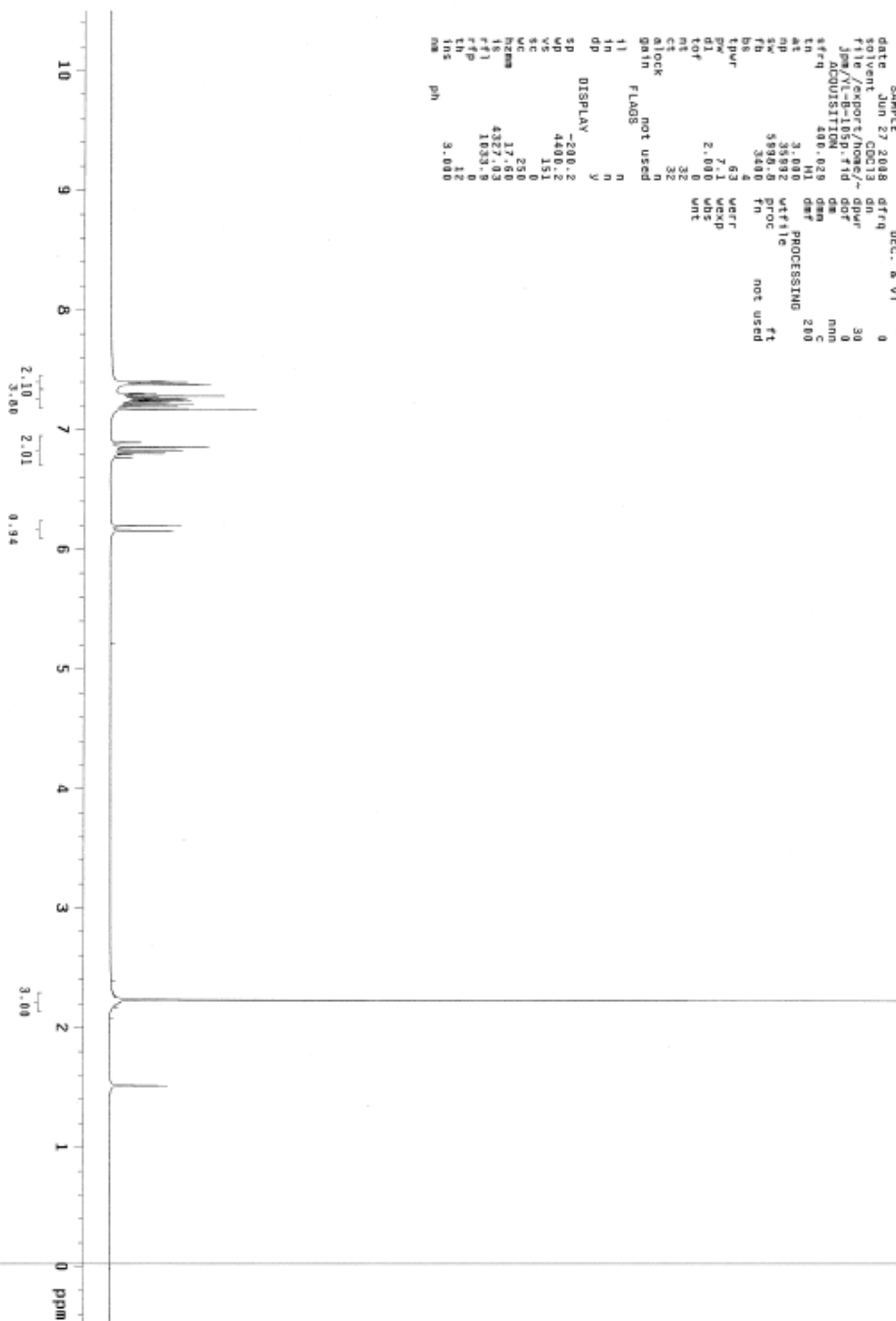
In a flame-dried 50 ml vial with a magnetic stir bar, 2.4 g (7.5 mmol) of 1-(triphenyl phospharanylidene)-2-propanone was diluted by 10.0 mL of toluene under nitrogen. 0.95 ml (0.0075 mmol) of trans-cinnamaldehyde was then added dropwise into the solution. After that, the vial was capped, taped and stirred under the temperature 110°C for 12 hours. Then the reaction was quenched with water and the aqueous layer was washed with methylene chloride (3 x 50ml). The organic layers were combined and washed with brine and dried with Na₂SO₄. After volatiles were removed, silica gel chromatography (hexanes/ethyl acetate) was used to give 1.04g (81% yield) of the desired product.



(3E,5E)-6-phenylhexa-3,5-dien-2-one. ¹H NMR (400 MHz, CDCl₃): δ 7.49-7.26 (6H, m), 6.98-6.94 (1H, d, *J*=15.6 Hz), 6.92-6.85 (1H, dd, *J*=15.6, 10.0 Hz),

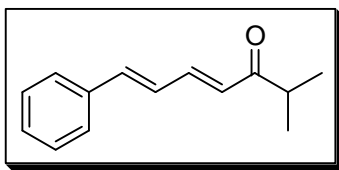
6.28-6.24 (1H, d, *J*=15.6 Hz), 6.322 (1H, s); ¹³C NMR (400 MHz, CDCl₃): δ 198.5 143.5 141.4 136.1 130.6 129.4 129.0 127.4 126.8 27.6; IR(neat): 3059 (w), 3027 (w), 1683 (m), 1667 (s), 1652 (s), 1613 (s), 1587 (s), 1495 (w), 1449 (w), 1424 (w), 1359 (m), 1314 (w), 1288 (w), 1249 (s), 1178 (w), 1142 (m), 1072 (w), 995 (s), 961 (w), 814 (w), 750 (s), 691 (s), 638 (w), 562 (w), 519 (w), 502 (w) cm⁻¹; LRMS (ESI⁺) Calc'd for C₁₂H₁₃O (M+H)⁺: 173.09664 Observed (M+H)⁺: 173.09640.

YL-B-185p
 P/L-2 reference: s2pu1
 exp1 std1h
 SAMPLE
 date Jun 27 2008 grq DEC. 8 VT 9
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 f1/cqpr3 100cd/-dpr 30
 JPM/1000 10 dm
 ACQUISITION
 grq 490.029 dm
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 mc 35882 wfile
 sw 5890.6 proc ft
 fb 3490 fn not used
 ba 4
 tpr 63 uet
 sw 71 wdp
 d1 2.000 wds
 tot 0 wnt
 ct 32
 cl 32
 clock 49
 gain not used
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 DISPLAY
 sp -200.2
 vp 4400.2
 vs 151
 vc 250
 hzmm 17.60
 18 4327.03
 f1 1033.8
 th 12
 ms 3.000
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VL-B-185p-carbon
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 exp1 std13c

SAMPLE
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 jpe/VL-B-185p-carb- dff
 exp1- f1d dam vyy
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 ac 0.640 1b
 ap 3.324 uff1b
 sq 25683.4 proc ft
 fd 14280 tn not used
 bs 6
 tpur 5g uert
 ac 6.2 uert
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 i1313 n
 i1314 n



(4*E*,6*E*)-2-methyl-7-phenylhepta-4,6-dien-3-one. ¹H

NMR (400 MHz, CDCl₃): δ 7.48-7.29 (6H, m),

6.98-6.94 (1H, d, *J*=15.6 Hz), 6.92-6.86 (1H, dd, *J*=9.6,

15.6 Hz), 6.39-6.35 (1H, d, *J*=15.2 Hz), 2.89-2.83 (1H, m), 1.16-1.15 (6H, d, *J*=7.2

Hz); ¹³C NMR (400 MHz, CDCl₃): δ 204.0 142.6 141.3 136.3 129.2 129.0 128.1

127.3 127.0 39.4 18.8; IR(neat): 3028 (w), 2968 (m), 2931 (w), 2872 (w), 1682 (m),

1658 (m), 1615 (m), 1586 (s), 1466 (m), 1448 (m), 1383 (m), 1352 (m), 1314 (w),

1286 (m), 1203 (s), 1151 (m), 1119 (w), 1048 (s), 998 (s), 842 (w), 753 (s), 690 (s),

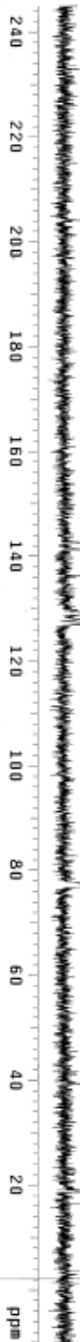
506 (w) cm⁻¹; LRMS (ESI+) Calc'd for C₁₄H₁₇O (M+H)⁺: 201.12794 Observed

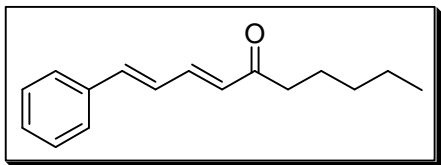
(M+H)⁺: 201.12841.

VL-A-SUBSTRATES-Carbon
 PULSED SPARK SOURCE 300 MHz

exp1 std13c

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 date Jul 1 2008 dfreq 400.029
 solvent CDCl3 gn H1
 file 1001301 exp dpar 45
 title 1001301 de 1001301
 ACQUISITION exp dpar 45
 dfreq 100.559 de 1001301
 tn C13 dem yyy
 at 0.640 def 3242
 ap 0.02876 lb PROCESSING 2.90
 ap 0.02876 lb
 fv 14260 wfile
 bs 4 proc not used
 tpar 50 fn
 gv 8.7 vert
 gv 4.00
 tof 2271.7 wexp
 nt 1800 wbs
 ct 160 wnt
 alock n
 gain not used
 flags
 11 n
 1n n
 gp y
 sp DISPLAY
 wp 25883.4
 vs 97
 sc 8
 vsc 258
 hzmm 182.73
 ts 580.08
 rfi 8825.8
 rfp 7766.3
 tms 4
 tms no ph 108.808





(1E,3E)-1-phenyldeca-1,3-dien-5-one. ¹H

NMR (400 MHz, CDCl₃): δ 7.48-7.30 (6H, m),

6.97-6.94 (2H, d, *J*=15.2 Hz), 6.91-6.85 (1H, dd,

J=15.2 Hz), 6.31-6.27 (1H, d, *J*=15.6 Hz), 2.61-2.57 (2H, t, *J*=7.2 Hz), 1.69-1.62 (2H,

m), 1.37-1.27 (4H, m), 0.92-0.89 (3H, t, *J*=6.8 Hz); ¹³C NMR (400 MHz, CDCl₃): δ

200.9 142.5 141.2 136.3 129.9 129.3 129.0 127.4 127.0 41.0 31.8 24.4 22.8 14.2;

IR(neat): 3060 (w), 3028 (w), 3000 (w), 2957 (m), 2930 (m), 2889 (w), 2854 (m),

1681 (s), 1586 (s), 1486 (m), 1467 (m), 1449 (m), 1406 (m), 1372 (s), 1317 (m), 1280

(m), 1245 (m), 1216 (m), 1179 (m), 1126 (s), 1073 (s), 1037 (m), 1007 (s), 998 (s),

959 (w), 924 (w), 884 (w), 851 (w), 811 (w), 757 (w), 746 (s), 722 (m), 688 (s), 617

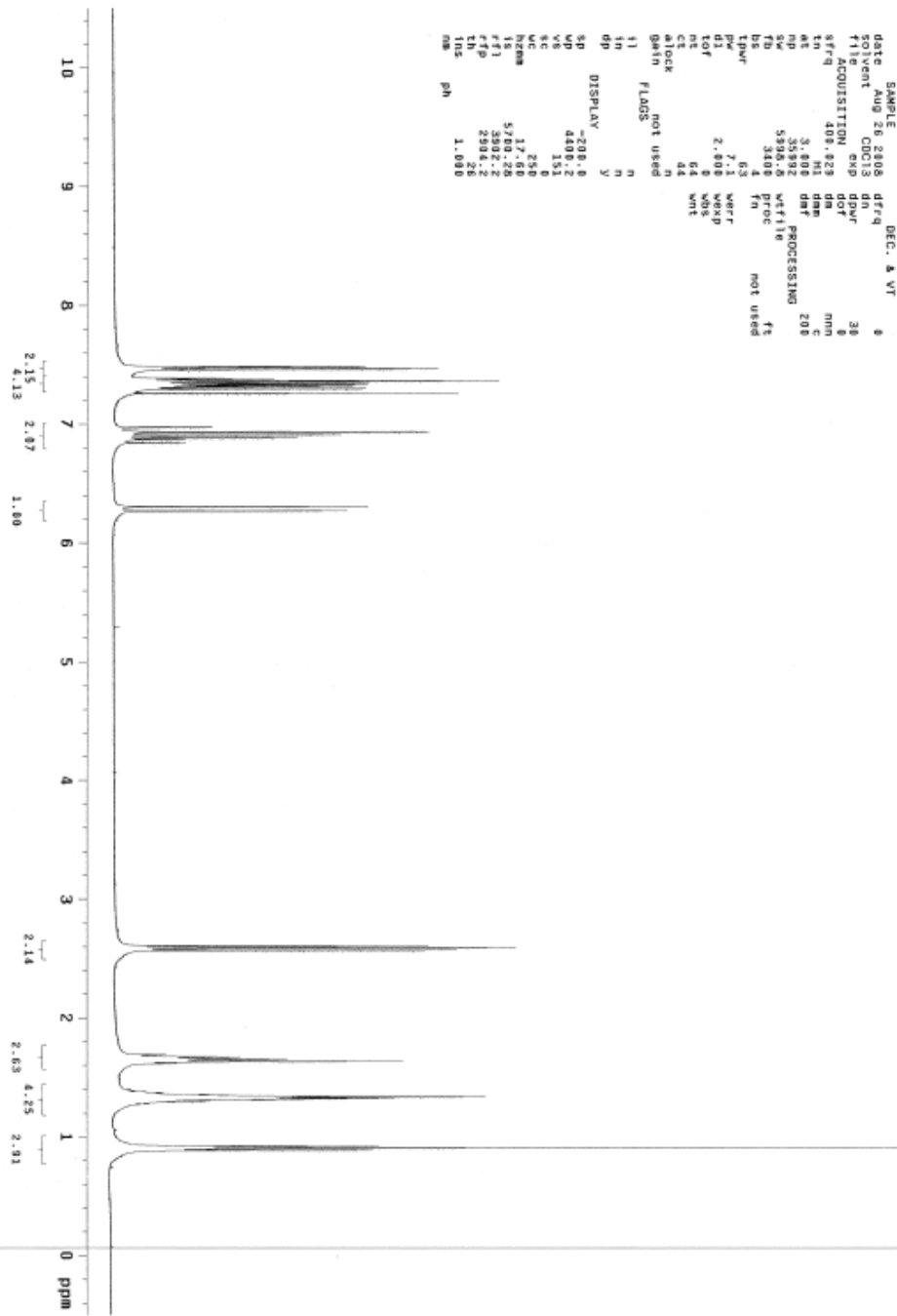
(w), 549 (w), 504 (m), 416 (m) cm⁻¹; LRMS (ESI+) Calc'd for C₁₆H₂₁O₁ (M+H)⁺:

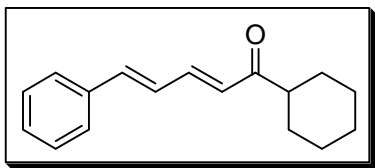
229.15924 Observed (M+H)⁺: 229.15958.

VL-A-21301
 PULSED-SEQUENCE: szpu1

exp1 std1h

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file	exp1	exp	30
acq	100.623	exp	30
to	3.800	exp	30
at	3.800	exp	30
sw	35992	exp	30
ns	380.4	exp	30
bs	6.3	exp	30
tpwr	7.1	exp	30
pw	2.800	exp	30
mt	64	exp	30
ct	44	exp	30
atlock	not used	exp	30
gain	not used	exp	30
flaos	not used	exp	30
fl	n	exp	30
in	n	exp	30
dp	y	exp	30
sd	DISPLAY	exp	30
wp	4400.2	exp	30
vs	131	exp	30
sc	250	exp	30
mc	1.7	exp	30
is	5700.20	exp	30
ff1	3902.2	exp	30
ffp	2904.2	exp	30
ffs	1.000	exp	30
ms	ph	exp	30





(2E,4E)-1-cyclohexyl-5-phenylpenta-2,4-dien-1-one.

^1H NMR (400 MHz, CDCl_3): δ 7.48-7.31 (6H, m),

6.97-6.85 (2H, m), 6.37-6.34 (1H, d, $J=15.2$ Hz),

2.61-2.55 (1H, m), 1.88-1.66 (6H, m), 1.45-1.24 (4H, m); ^{13}C NMR (400 MHz,

CDCl_3): δ 203.4, 142.4, 141.2, 136.3, 129.2, 128.9, 128.4, 127.3, 127.0, 49.4, 29.0,

26.2, 26.0; IR(neat): 3027 (w), 2925 (s), 2852 (s), 1677 (m), 1650 (m), 1614 (w),

1584 (s), 1447 (m), 1371 (m), 1343 (m), 1315 (m), 1290 (m), 1244 (m), 1192 (m),

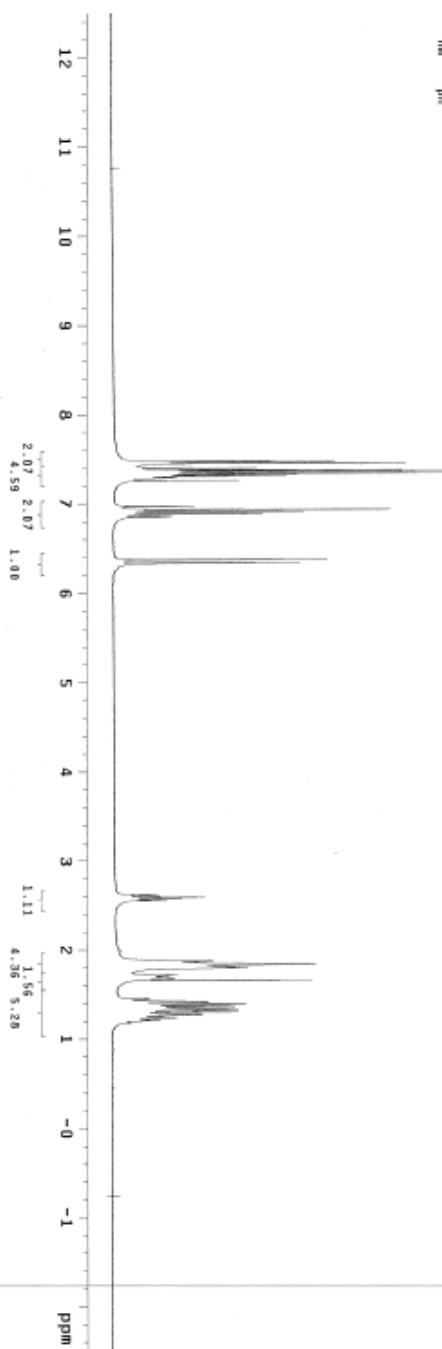
1168 (m), 1141 (m), 1081 (s), 1063 (w), 996 (s), 947 (w), 921 (w), 887 (w), 826 (w),

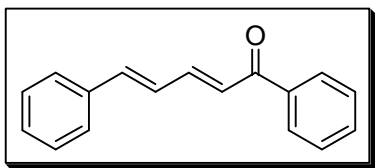
793 (w), 751 (s), 690 (s), 506 (m), 394 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{17}\text{H}_{21}\text{O}$

$(\text{M}+\text{H})^+$: 241.15924 Observed $(\text{M}+\text{H})^+$: 241.15983.

VL-A-147P
 p1/c6-364/Name: 82pu1
 exp1 std1h

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jpse	VL-A-147P.fid	dot	0
acq	500.029	mm	0
to	500.029	mm	0
at	3.000	width	0
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sp	35992	proc	0
fb	35992	proc	0
bs	4	not used	0
tpur	63	width	0
pw	7.1	width	0
pr	2.000	width	0
nt	32	width	0
ct	32	width	0
alock	not used	width	0
gain	not used	width	0
11	n	width	0
10	n	width	0
dp	y	width	0
sp	DISPLAY-000.1	width	0
vp	5000.0	width	0
v5	62	width	0
vc	0	width	0
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vcmm	18	width	0
rfl	13631.04	width	0
rfl	3903.3	width	0
rfl	2904.2	width	0
lms	1.000	width	0
ms	1.000	width	0





(2E,4E)-1,5-diphenylpenta-2,4-dien-1-one. ^1H

NMR (400 MHz, CDCl_3): δ 8.00-7.98 (2H, d, $J=6.0$ Hz), 7.65-7.30 (9H, m), 7.12-7.08 (1H, d, $J=14.8$ Hz),

7.04-7.02 (2H, m); ^{13}C NMR (400 MHz, CDCl_3): δ 190.5 144.9 142.0 138.4 136.3

132.8 129.4 129.0 128.7 128.5 127.4 127.1 125.6; IR(neat): 3058 (w), 3026 (w), 2918

(w), 2849 (w), 1655 (s), 1599 (s), 1583 (s), 1573 (s), 1494 (w), 1447 (m), 1351 (s),

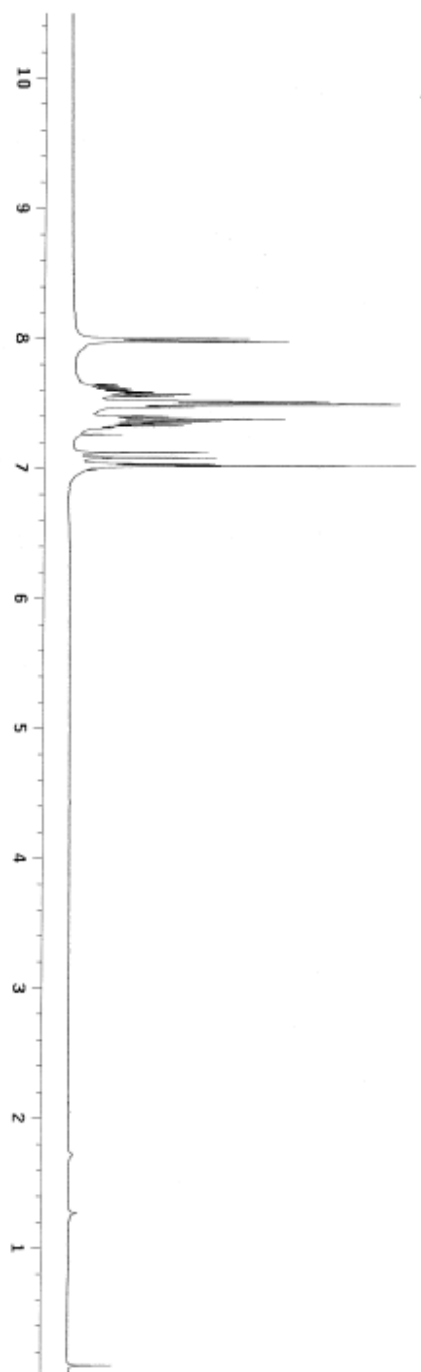
1286 (s), 1250 (s), 1199 (w), 1178 (w), 1150 (m), 1072 (w), 1033 (w), 1015 (s), 998

(s), 879 (w), 845 (m), 775 (m), 748 (m), 693 (s), 667 (m), 504 (w) cm^{-1} ; LRMS (ESI+)

Calc'd for $\text{C}_{17}\text{H}_{15}\text{O}_1$ ($\text{M}+\text{H}$) $^+$: 235.11229 Observed ($\text{M}+\text{H}$) $^+$: 235.11257.

VL-B-132PP
 P:\583\Reference: 52pu1
 exp5 std1h

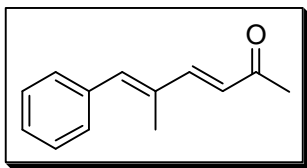
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 date Aug 4 2000 dfrq 0
 solvent CDCl3 on 30
 f1 JMODPORT/NOE/4 dfr 30
 jpu/VL-B-132PP f16 dm 0
 ACQUISITION
 sfrq 400.029 dm 200
 tn H1 daf
 at 3.000 WET 16 PROCESSING
 ap 55392 FIDOC FT
 fb 2400 FN not used
 bs 4
 tpuv 63 wcp
 pu 7.1 wcp
 ol 2.00 wos
 tot 8 wot
 nti 32
 ct 32
 alock n
 gain not used
 flags
 11 n
 1m n
 dp n
 DISPLAY y
 sp -200.0
 wp 4400.2
 vs 60
 sc 0
 wc 250
 17.50
 15 500.00
 f1 3900.2
 f1p 2900.2
 th 20
 ins 100.000
 ph



exps	std130
------	--------

nm no ph

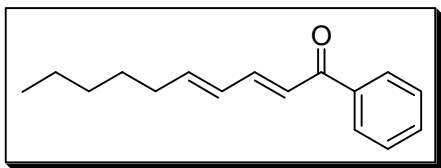




(3E,5E)-5-methyl-6-phenylhexa-3,5-dien-2-one. ^1H

NMR (400 MHz, CDCl_3): δ 7.39-7.30 (6H, m), 6.90 (1H, s), 6.28-6.24 (1H, d, $J=16.0$), 2.35 (3H, s), 2.06 (3H, s);

^{13}C NMR (400 MHz, CDCl_3): δ **198.8**, 148.9, 139.9, 136.8, 134.6, 129.6, 128.6, 128.1, 126.9, 27.8, 14.0; IR(neat): 3050 (w), 3021 (w), 2918 (w), 2861 (w), 1685 (m), 1665 (s), 1605 (s), 1586 (s), 1490 (w), 1444 (w), 1395 (w), 1359 (s), 1295 (m), 1255 (s), 1209 (m), 1174 (w), 1078 (m), 1024 (s), 970 (w), 922 (w), 882 (w), 827 (m), 749 (s), 698 (s), 663 (w), 587 (w), 555 (m), 515 (w), 461 (m); LRMS (ESI+) Calc'd for $\text{C}_{13}\text{H}_{15}\text{O}_1$ ($\text{M}+\text{H}$) $^+$: 187.11229 Observed ($\text{M}+\text{H}$) $^+$: 187.11205.



(2E,4E)-1-phenyldeca-2,4-dien-1-one. ^1H

NMR (400 MHz, CDCl_3): δ 7.94-7.92 (3H, m),

7.54-7.38 (3H, m), 6.90-6.86 (1H, d, $J=14.8$)

6.35-6.22 (2H, m), 2.21-2.18 (2H, m), 1.47-1.31 (6H, m), 0.89-0.88 (3H, m); ^{13}C

NMR (400 MHz, CDCl_3): δ 191.1, 146.8, 145.6 138.5 132.6 129.3 128.6 128.5 123.7

33.4 31.6 28.6 22.7 14.2; IR(neat): 3059 (w), 3027 (w), 2955 (m), 2926 (s), 2857 (m),

1661 (s), 1625 (m), 1587 (s), 1447 (m), 1352 (w), 1254 (s), 1211 (w), 1179 (w), 1157

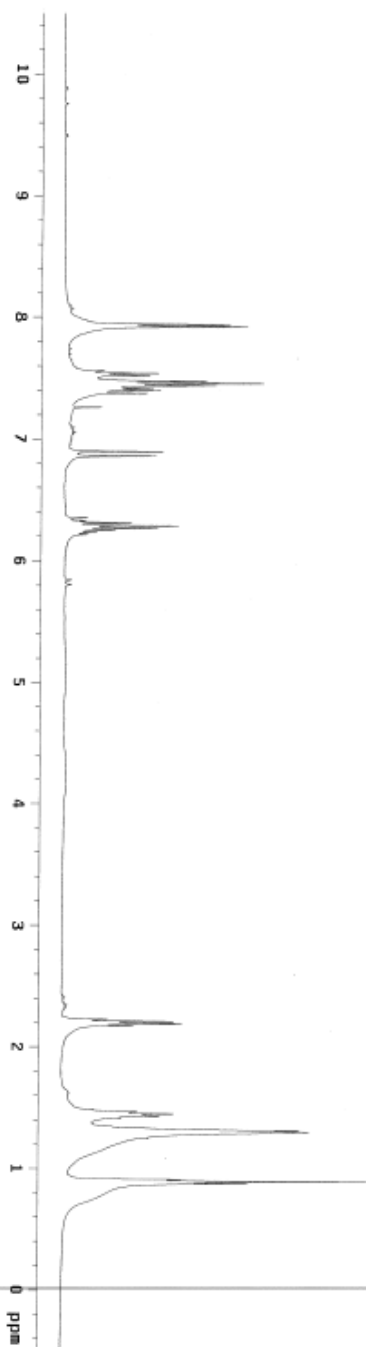
(R) (w), 1114 (w), 1072 (w), 1034 (w), 1000 (s), 874 (w), 833 (m), 769 (m), 693 (s),

665 (m), 617 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{16}\text{H}_{21}\text{O}_1$ ($\text{M}+\text{H}$) $^+$: 229.15924

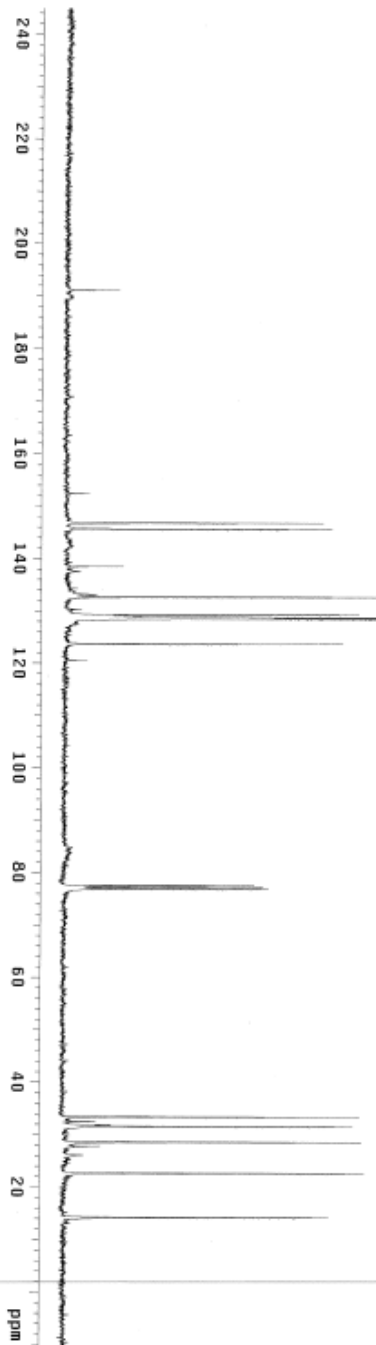
Observed ($\text{M}+\text{H}$) $^+$: 229.16025.

YL-A-259p
PULSED SEQUENCE: szpu1
exp5 std1h

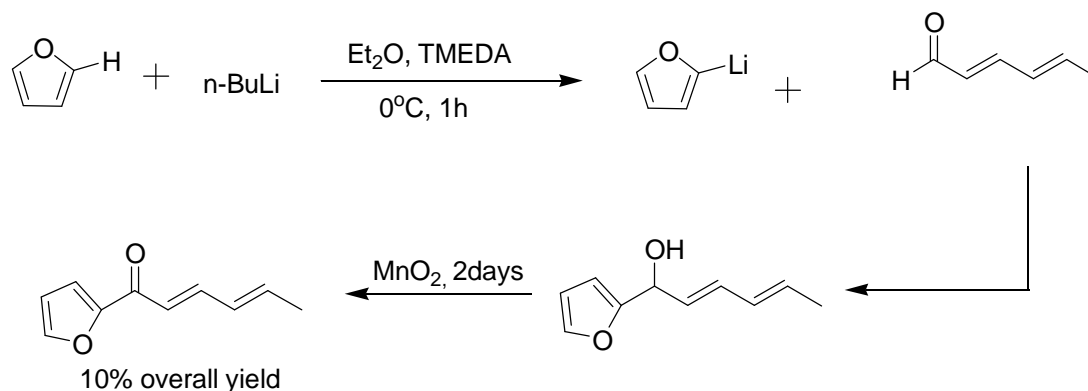
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solvent CDCl3 dn
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jpa /export/home/~dpur 30
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sfrq 400.029 dnm
tn H1 dat 208
nt 3.000 1b PROCESSING 0.58
no 3.000 1b
sv 53852 wflie
fb 3400 proc ft
bs 4 tn not used
tdw 63 uscf
dt 71 uscf
nt 2.000 wsf
tof 0 wsf
nt 32 wnt
ct 32
nlock n
data not used
flags
11 n
1n n
dp y
sp DISPLAY -208.0
vp 4408.2
vs 57
vc 58
hnm 17.60
is 590.00
f1 3800.2
f2 2900.2
t0 20
tms 100.000
ph



VL-A-258p-carbon
 PULSED SPIN ECHO
 exp1 8td13c
 SAMPLE
 date Aug 25, 2008 dfrq DEC. 6 VT
 solvent CMCIS dm
 file ACQUISITION exp dfr 45
 to 101.589 dm
 at 0.640 dm 3242
 mp 32876 1b PROCESSING 3.80
 sv 25883.4 1b
 bz 14284 4 proc ft
 tpar 58 fn not used
 pw 8.7 weff
 dc 4.000 weff
 tc 2.047 weff
 nt 1000 mbp
 ct 1000 unit
 atock not used
 gain FLAOS n
 1) n
 tn n
 gp y
 DISPLAY
 sp 1058.2
 mp 25883.4
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 wc 102.250
 zc 102.250
 f1 500.00
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 me no ph

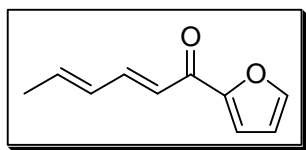


Procedure for the synthesis of (2*E*,4*E*)-1-(furan-2-yl)hexa-2,4-dien-1-one:



In a flame-dried 100 ml round bottom flask with a magnetic stir bar, 3.6 ml (50.0 mmol) of furan was diluted by 30.0 ml of diethyl ether under nitrogen. After the solution was cooled to 0°C, tetramethylethylenediamine (7.6 ml) and *n*-butyllithium (22.0 ml, 2.27M, 50.0 mmol) were then added dropwise into the solution. After that, the solution was stirred under the temperature 0°C for 1 hours. Then the solution was cooled to -78°C and trans,trans-2,4-hexadienal (5.4 ml, 50.0 mmol) was added dropwise. After 12 hours, the reaction was quenched with water and the aqueous layer was washed with methylene chloride (3 x 50ml). The organic layers were combined and washed with brine and dried with Na₂SO₄. After volatiles were removed, it gave the crude product, (2*E*,4*E*)-1-(furan-2-yl)hexa-2,4-dien-1-ol.

To another flame-dried 100ml round bottom flask, the crude product (2*E*,4*E*)-1-(furan-2-yl)hexa-2,4-dien-1-ol, manganese oxide and dichloromethane were added under nitrogen. After stirring for another 42 hours, the reaction was filtered by celite. After volatiles were removed, silica gel chromatography (hexanes/ethyl acetate 20:1) was used to give 0.3 g (10% overall yield) of the desired product.



(2E,4E)-1-(furan-2-yl)hexa-2,4-dien-1-one. ^1H NMR

(400 MHz, CDCl_3): δ 7.61-7.60 (1H, m), 7.50-7.43 (1H, m),

7.26-7.22 (1H, m), 6.79-6.75 (1H, d, $J=15.2$ Hz), 6.57-6.54

(1H, m), 6.36-6.23 (2H, m), 1.90-1.89 (3H, d, $J=4.0$ Hz); ^{13}C NMR (400 MHz,

CDCl_3): δ 178.6 153.9 146.4 144.5 141.5 130.6 122.7 117.2 112.5 19.2; IR(neat):

3121 (m), 3093 (w), 3015 (w), 2964 (w), 2939 (w), 2914 (w), 2844 (w), 1653 (s),

1627 (m), 1587 (s), 1557 (w), 1464 (s), 1396 (s), 1341 (m), 1281 (s), 1217 (w), 1162

(m), 1085 (m), 998 (s), 940 (w), 922 (w), 899 (w), 874 (w), 852 (w), 798 (m), 769 (m),

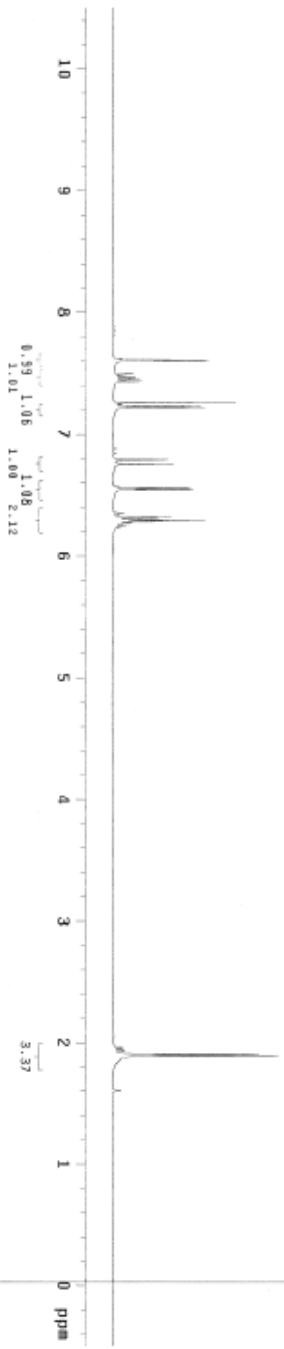
726 (w), 704 (w), 594 (w), 543 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{10}\text{H}_{11}\text{O}_2$ ($\text{M}+\text{H}$) $^+$:

163.07590 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 163.07608.

YL-B-016P-H
 PULSED 300MHz: 12pu)

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at 3.000 dm 280
no 3.000 dm 280
sv 5000.0 wflr 280
fb 3000 proc ft
bs 4 fn not used
tpur 63 wflr 280
wv 71 wflr 280
ol 2.000 wexp 280
tof 0 wbs 280
nt 32 wnt 280
ct 32 wnt 280
clock 32 wnt 280
gain not used
flags 11 n
10 n
dp y
sp DISPLAY -280.0
vp 440.0
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nm ph
  
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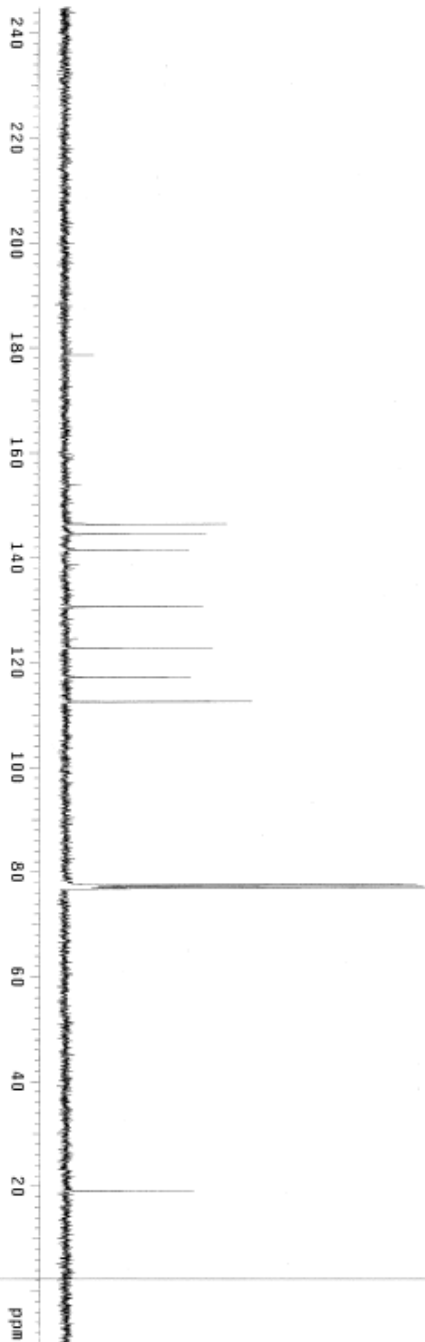
VL-B-016p-carbon
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exp1 std130
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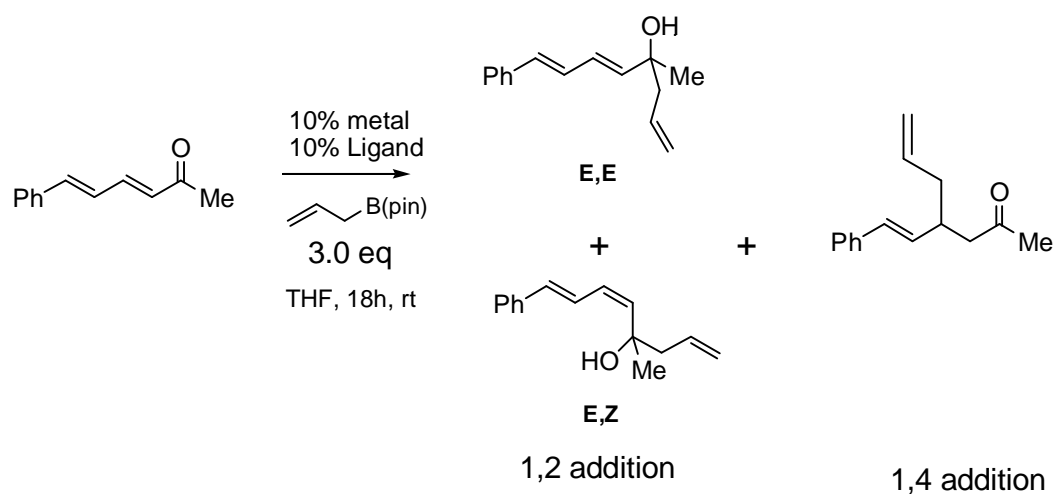
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T1 acquisition exp dn 1.49
dfreq 100.599 dpr 4
C13 dm 0.610
C13 dam 0.610
dam PROCESSING 9342
V U V 2.08
n 1b wFile
bs 6 proc T1
tspur 85 not used
g1 4.000 verr
tof 2271.7 wepp
at 1000 whs
t1 828 unt
lock gain not used
flags
1 1 n
dn y
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v 0
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hzm 508.80
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ctfp 20
ins no ph 100.000

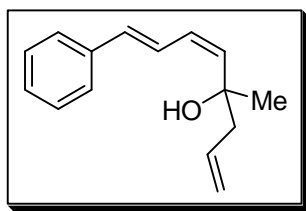
```



Typical procedure for nickel catalyzed allylation of dienone:



To a flame-dried 10 ml vial with a magnetic stir bar, 3.2 mg (0.0116 mmol) of bis(1,5-cyclooctadiene)nickel, 3.3 mg (0.0116 mmol) of tricyclohexylphosphine, and 0.23 mL of THF were added in a glove-box under an argon atmosphere. The vial was capped and stirred for 10 min, before adding 58.5 mg (0.348 mmol) of allylboronic acid pinacol ester, followed by 26.5 mg (0.116 mmol) of (1E,3E)-1-phenyldeca-1,3-dien-5-one. The vial was sealed, removed from the glove-box and stirred at room temperature for 18 hours. Then the reaction was quenched by water and the aqueous layer was washed with methylene chloride (3 x 10ml). The organic layers were combined and washed with brine and dried with Na₂SO₄. After volatiles were removed, silica gel chromatography (hexanes/ethyl acetate 30:1) was used to give 29.6 mg (95% yield) of the desired product as an oil.



(5Z,7E)-4-methyl-8-phenylocta-1,5,7-trien-4-ol. ^1H NMR

(400 MHz, CDCl_3): δ 7.74-7.67 (1H, dd, $J=15.6, 11.6$ Hz)

7.44-7.20 (5H, m), 6.51-6.47 (1H, d, $J=16.0$ Hz), 6.18-6.12

(1H, t, $J=11.2$ Hz), 5.90-5.85 (1H, m), 5.53-5.50 (1H, d, $J=11.6$ Hz), 5.21-5.15 (2H,

m), 2.50-2.33 (2H, m), 1.87 (1H, s), 1.43 (3H, s); ^{13}C NMR (400 MHz, CDCl_3): δ

137.5 136.9 134.2 133.8 129.9 128.7 127.7 126.8 125.8 119.5 74.1 48.8 29.5;

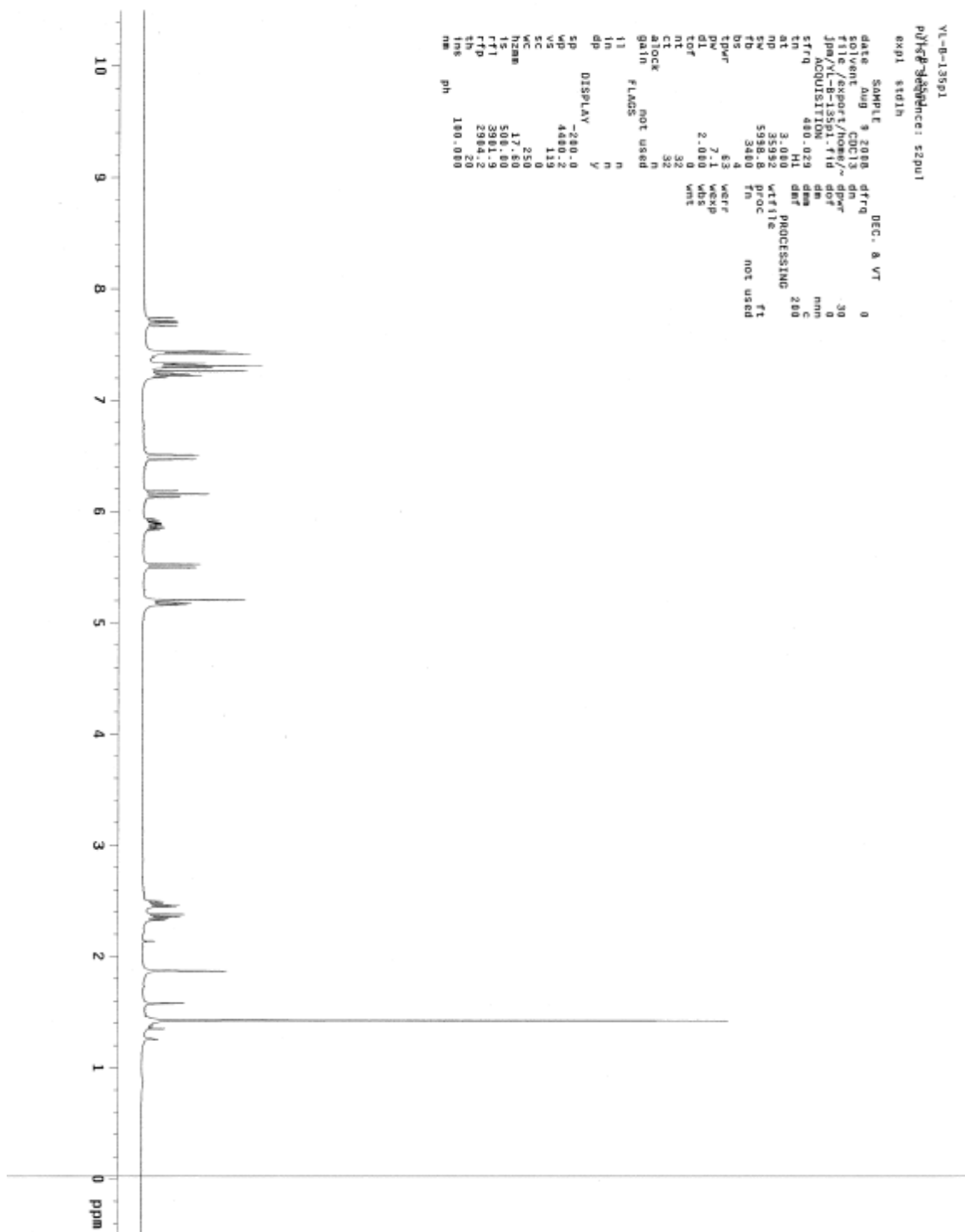
IR(neat): 3413 (br), 3025 (m), 2923 (m), 2853 (m), 1713 (w), 1459 (m), 1376 (m),

1260 (w), 1114 (w), 1048 (w), 990 (s), 915 (s), 746 (s), 691 (s) cm^{-1} ; LRMS (ESI+)

Calc'd for $\text{C}_{15}\text{H}_{17}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$): 197.13303 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 197.13351.

VL-B-135p1
 P0768-Sequence: s2pu1
 exp1 161h

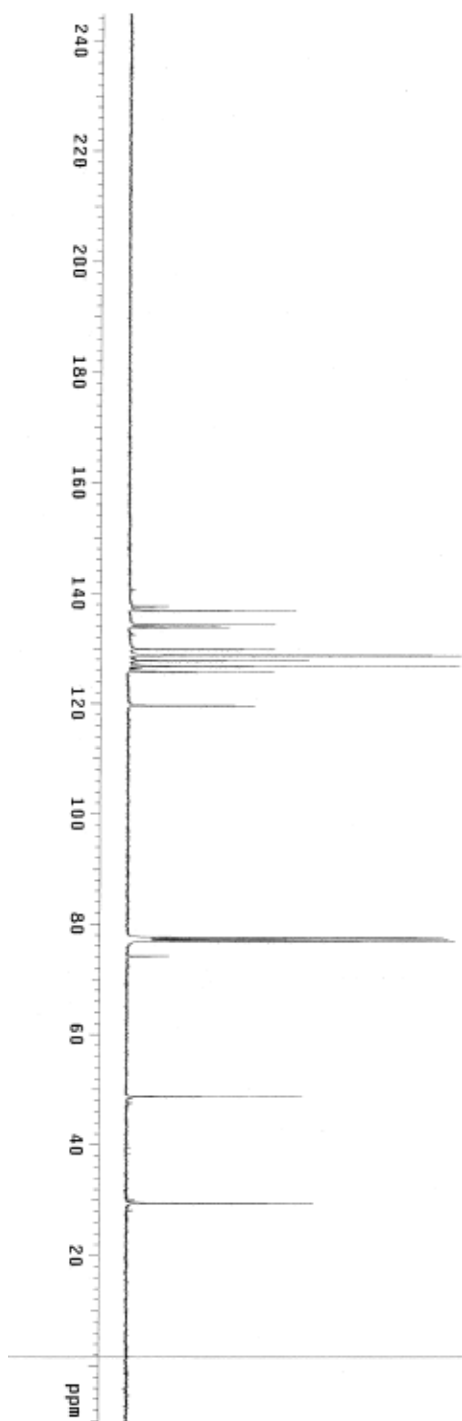
date	aug 9 2008	dec. & vt	0
solvent	d2o		
file	/export/home/~dpw		30
jpq/vl-b-135p1.fid		dm	mm
ACQUISITION			
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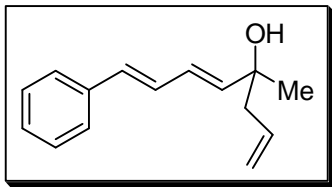


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(5E,7E)-4-methyl-8-phenylocta-1,5,7-trien-4-ol. ^1H

NMR (400 MHz, CDCl_3): δ 7.40-7.20 (5H, m), 6.81-6.74 (1H, dd, $J=12.0, 16.0$ Hz), 6.57-6.53 (1H, d, $J=16.0$ Hz),

6.45-6.38 (1H, dd, $J=12.0, 16.0$ Hz), 5.92-5.88 (1H, d, $J=15.2$), 5.87-5.77 (1H, m),

5.19-5.13 (2H, m), 2.43-2.29 (2H, m), 1.35 (3H, s); ^{13}C NMR (400 MHz, CDCl_3): δ

140.6 137.5 133.7 132.4 128.8 128.6 128.2 127.6 126.5 119.5 47.5 30.0 28.2;

IR(neat): 3413 (br), 3077 (w), 3025 (m), 2957 (m), 2923 (s), 2853 (m), 1713 (w),

1640 (w), 1493 (w), 1459 (m), 1376 (m), 1260 (w), 1114 (w), 1048 (w), 990 (s), 915

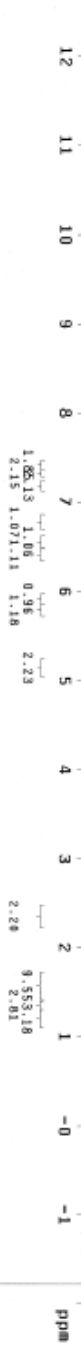
(s), 746 (s), 691 (s) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{15}\text{H}_{17}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 197.13303

Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 197.13351.

VL-B-110P2
 P11-2-24-1999: s2pu1

exp2 std1h

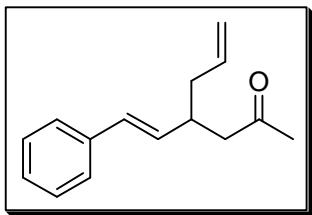
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nm	ph		



exp5 std13c

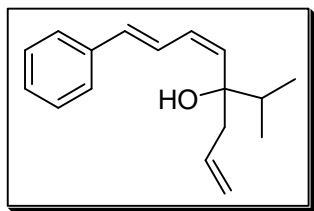
na
no
ph





(E)-4-styrylhept-6-en-2-one. ^1H NMR (400 MHz, CDCl_3): δ 7.34-7.18 (5H, m), 6.41-6.37 (1H, d, $J=16.0$ Hz), 6.10-6.04 (1H, dd, $J=16.0, 8.0$ Hz), 5.82-5.71 (1H, m),

5.08-5.02 (2H, m), 2.91-2.83 (1H, m), 2.62-2.48 (2H, m), 2.24-2.20 (2H, m), 2.14 (3H, s); ^{13}C NMR (400 MHz, CDCl_3): δ 207.9, 136.1, 132.7, 130.4, 128.7, 127.4, 126.3, 117.1, 48.5, 39.6, 38.3, 31.0, 30.0; IR(neat): 3078 (w), 3026 (w), 2922 (s), 2852 (m), 1715 (s), 1640 (w), 1599 (w), 1493 (w), 1448 (m), 1416 (w), 1357 (m), 1287 (m), 1160 (m), 1126 (w), 1073 (w), 966 (s), 914 (s), 747 (s), 694 (s), 581 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{15}\text{H}_{19}\text{O}_1$ ($\text{M}+\text{H}$) $^+$: 215.14359 Observed ($\text{M}+\text{H}$) $^+$: 215.14466.



(5Z,7E)-4-isopropyl-8-phenylocta-1,5,7-trien-4-ol. ^1H

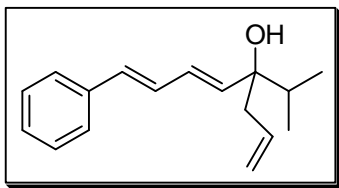
NMR (400 MHz, CDCl_3): δ 7.80-7.73 (1H, dd, $J=11.2$, 16.2 Hz), 7.43-7.29 (4H, m), 7.27-7.19 (1H, m), 6.49-6.45

(1H, d, $J=15.6$ Hz), 6.29-6.23 (1H, t, $J=12.0$ Hz), 5.92-5.81 (1H, m), 5.40-5.37 (1H, d, $J=12$ Hz), 5.20-5.16 (2H, m), 2.58-2.31 (2H, m), 1.90-1.84 (3H, m), 1.82 (1H, s), 1.01-0.97 (6H, m); ^{13}C NMR (400 MHz, CDCl_3): δ 137.8 134.4 134.1 134.0 131.1 128.7 127.6 126.7 126.6 119.6 79.3 44.7 37.9 18.0 17.1; IR(neat): 3562 (br), 3075 (w), 3004 (w), 2962 (s), 2932 (m), 2875 (w), 1709 (w), 1637 (m), 1599 (w), 1493 (m), 1468 (m), 1448 (m), 1385 (m), 1366 (w), 1272 (w), 1156 (w), 1103 (w), 1071 (w), 1024 (w), 992 (s), 955 (m), 914 (s), 888 (w), 863 (w), 741 (s), 691 (s), 565 (w), 483 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{17}\text{H}_{21}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 225.16433 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 225.17203.

emp5 std13c

yd ou



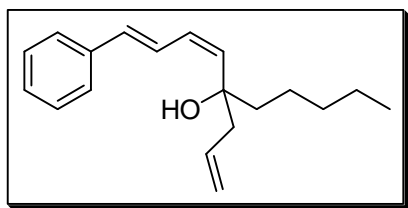


(5E,7E)-4-isopropyl-8-phenylocta-1,5,7-trien-4-ol.

^1H NMR (400 MHz, CDCl_3): δ 7.41-7.29 (4H, m),
7.23-7.19 (1H, m), 6.84-6.78 (1H, dd, $J=15.8, 10.8$ Hz),

6.56-6.52 (1H, d, $J=12.0, 16.0$ Hz), 6.45-6.38 (1H, dd, $J=11.2, 15.6$ Hz), 5.86-5.82
(1H, d, $J=16.0$ Hz), 5.85-5.74 (1H, m), 5.19-5.13 (2H, m), 2.47-2.29 (2H, m),
1.84-1.77 (1H, m), 1.67 (1H, s), 0.95-0.93 (6H, m); ^{13}C NMR (400 MHz, CDCl_3): δ
138.1, 137.6, 133.9, 131.9, 129.9, 128.8, 127.5, 126.4, 119.5, 76.8, 43.7, 37.2, 30.0,
17.9, 17.0; IR(neat): 3569 (br), 3078 (w), 3024 (w), 2960 (s), 2926 (s), 2874 (w),
2854 (w), 1726 (w), 1639 (w), 1494 (m), 1466 (m), 1448 (m), 1414 (w), 1070 (w),
1171 (w), 1125 (w), 990 (s), 916 (m), 746 (s), 691 (s) 508 (w) cm^{-1} ; LRMS (ESI+)
Calc'd for $\text{C}_{17}\text{H}_{21}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 225.16433 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 225.16435.

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 f1315 n



(1E,3Z)-5-allyl-1-phenyldeca-1,3-dien-5-ol. ¹H

NMR (400 MHz, CDCl₃): δ 7.75-7.68 (1H, m),

7.44-7.41 (2H, m), 7.33-7.29 (2H, m), 7.24-7.20

(1H, m), 6.47 (1H, d, *J*=16.0 Hz), 6.20 (1H, t, *J*=16.0 Hz), 5.90-5.81 (1H, m),

5.42-5.39 (1H, d, *J*=11.6 Hz), 5.19-5.15 (2H, m), 2.49-2.30 (2H, m), 1.84 (1H, s),

1.66-1.57 (2H, m), 1.44-1.26 (6H, m), 0.90-0.88 (3H, m); ¹³C NMR (400 MHz,

CDCl₃): δ 137.7 136.0 134.1 133.8 130.4 128.7 127.6 126.8 126.2 119.5 76.8 47.3

42.3 32.5 23.7 22.9 14.3; IR(neat): 3359 (br), 3076 (w), 3005 (w), 2931 (s), 2859 (m),

1723 (w), 1638 (w), 1493 (m), 1448 (m), 1377 (m), 1271 (m), 1027 (s), 992 (s), 953

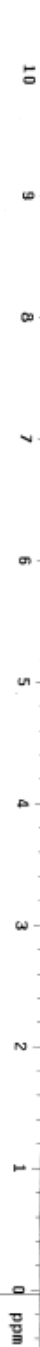
(m), 913 (m), 740 (s), 691 (s) cm⁻¹; LRMS (ESI+) Calc'd for C₁₉H₂₅ (M-H₂O+H)⁺:

253.19508 Observed (M-H₂O+H)⁺: 253.20197.

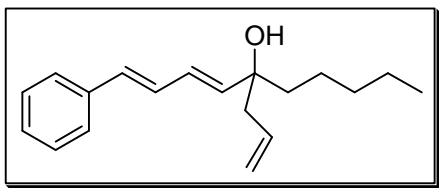
YL-A-218p
 PULSED-SEQUENCE: szpu1

exp1 std1h

SAMPLE		REC. A VT	
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solvent	CDCl3	dn	30
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name	YL-A-218p	df	0
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freq	400.029	dem	200
to	HI	def	200
at	3.080	PROCESSING	
sv	5988.8	proc	ft
fb	3480	fn	not used
ds	4	uerr	
dpwr	63	uerr	
ol	4.000	uerr	
tof	0	uerr	
nt	32	uerr	
st	32	uerr	
clock	not used	uerr	
data	not used	uerr	
flags	not used	uerr	
in	n	uerr	
dp	y	uerr	
sp	-200.8	uerr	
wp	4400.2	uerr	
vc	113	uerr	
wc	250	uerr	
hzam	17.60	uerr	
ts	500.00	uerr	
ft1	3982.8	uerr	
ft2	2384.20	uerr	
th	180.080	uerr	
ph	180.080	uerr	



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(1E,3E)-5-allyl-1-phenyldeca-1,3-dien-5-ol. ^1H

NMR (400 MHz, CDCl_3): δ 7.41-7.19 (5H, m),

6.83-6.76 (1H, dd, $J=10.4, 15.6$ Hz), 6.56-6.52

(1H, d, $J=16.0$ Hz), 6.43-6.37 (1H, dd, $J=10.4, 15.2$ Hz), 5.85-5.81 (1H, d, $J=15.6$ Hz),

5.84-5.75 (1H, m), 5.18-5.13 (2H, m), 2.42-2.27 (2H, m), 1.69 (1H, s), 1.64-1.51 (2H,

m), 1.37-1.24 (6H, m), 0.90-0.88 (3H, m); ^{13}C NMR (400 MHz, CDCl_3): δ 139.9

137.6 133.7 132.1 128.9 128.8 128.7 127.6 126.5 119.5 74.6 46.1 41.4 32.5 23.5 22.9

14.3; IR(neat): 3471 (br), 3077 (w), 3024 (w), 2954 (m), 2930 (s), 2858 (m), 1495 (w),

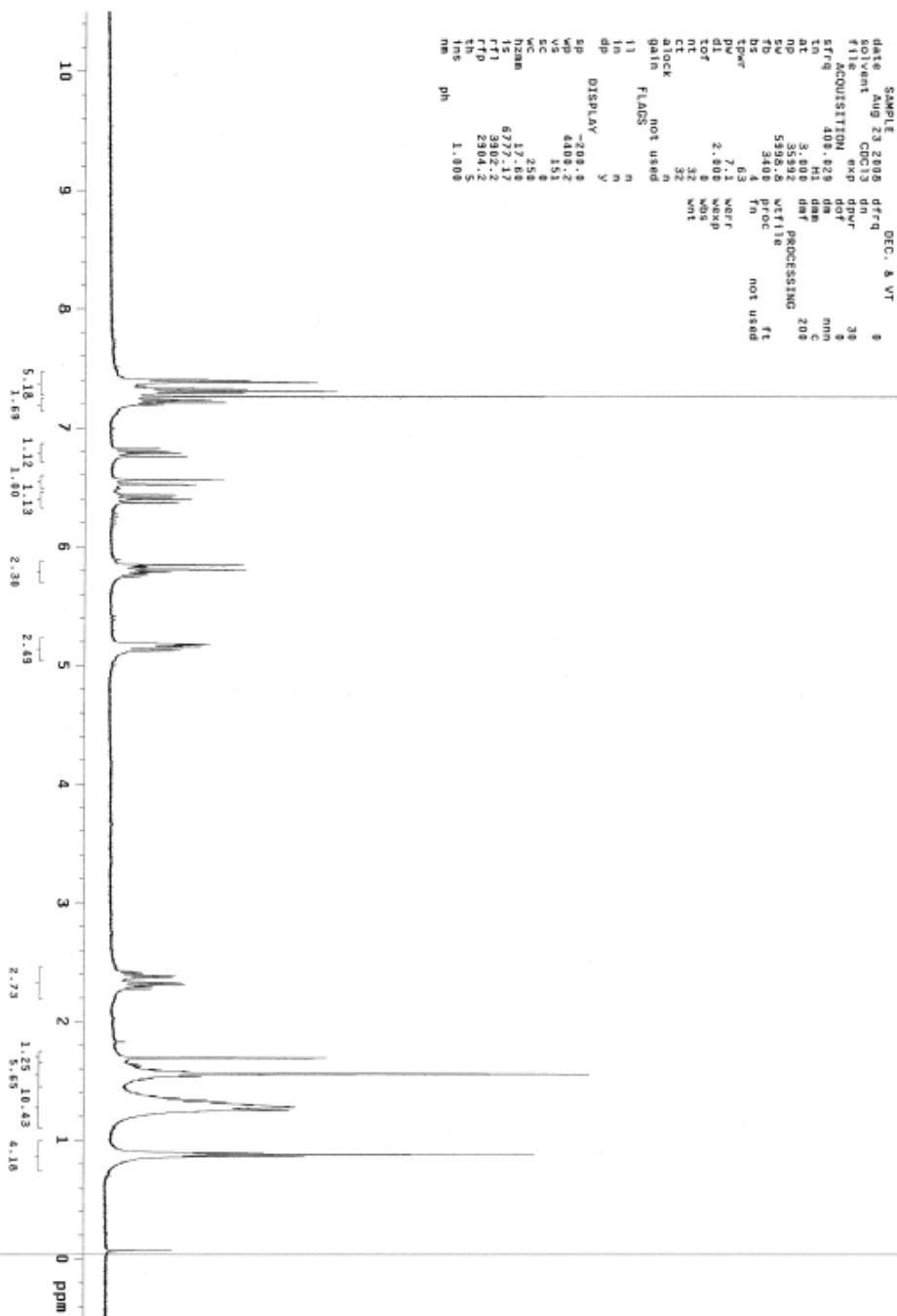
1448 (w), 1415 (w), 1378 (w), 1296 (w), 1261 (w), 1072 (w), 990 (s), 915 (m), 747

(s), 692 (s), 505 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{19}\text{H}_{25}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 253.19563

Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 253.22331.

VL-8-141P3
 PULSED-SEQUENCE: s2pu1
 exp1 std1h

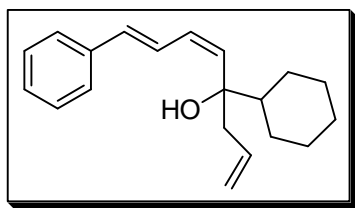
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 to H1 dm 38
 at 3.800 dnt 208
 no 55592 vefl 18
 to 55592 proc 4
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 tpwr 63 not used
 pu 7.1 weff
 tof 2.808 msp
 nt 32 wnt
 ct 32
 alock not used
 gain FLACS
 11 n
 1a n
 dp y
 sp DISPLAY -208.8
 wp 4408.2
 vs 151
 sc 358
 vsc 17.88
 hzmm 6777.17
 rfi 3802.2
 rfp 2804.2
 rfs 1.000
 nm ph



VL-8-141P3-carbon
 PULVER-24141P3-carbon

exp1 std13c

SAMPLE DEC. 8 VT
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 file ACQUISITION exp dpr 45
 srq 100.629 dpr 45
 in 100.629 dpr 45
 at 8.448 dat 9242
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 pw 18.04 wffile
 bs 4 proc ft
 tpr 5.6 in not used
 pr 8.7 werr
 dr 4.08 werr
 do 22.17 werr
 nt 10808 werr
 ct 1764 werr
 alock not used
 gain not used
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(5Z,7E)-4-cyclohexyl-8-phenylocta-1,5,7-trien-4-ol.

^1H NMR (400 MHz, CDCl_3): δ 7.78-7.71 (1H, dd, $J=11.6, 15.6$ Hz), 7.42-7.19 (5H, m), 6.47-6.43 (1H, d,

$J=15.6$ Hz), 6.26-6.20 (1H, t, $J=11.6$ Hz), 5.90-5.80 (1H, m), 5.38-5.35 (1H, d, $J=12.0$

Hz), 5.19-5.15 (2H, m), 2.56-2.21 (2H, m), 1.82 (1H, s), 1.97-0.82 (11H, m); ^{13}C

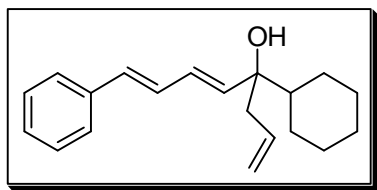
NMR (400 MHz, CDCl_3): δ 137.8 134.9 134.0 130.8 128.7 127.6 126.8 126.7 119.7

79.1 48.3 44.8 30.0 28.0 27.0 26.8; IR(neat): 3566 (br), 3077 (w), 3024 (w), 2927 (s),

2852 (m), 1638 (w), 1596 (w), 1495 (w), 1448 (m), 1347 (w), 1261 (w), 1158 (w),

1071 (w), 992 (s), 915 (m), 814 (w), 747 (m), 692 (m) cm^{-1} ; LRMS (ESI+) Calc'd for

$\text{C}_{20}\text{H}_{25}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 265.19563 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 265.19433.

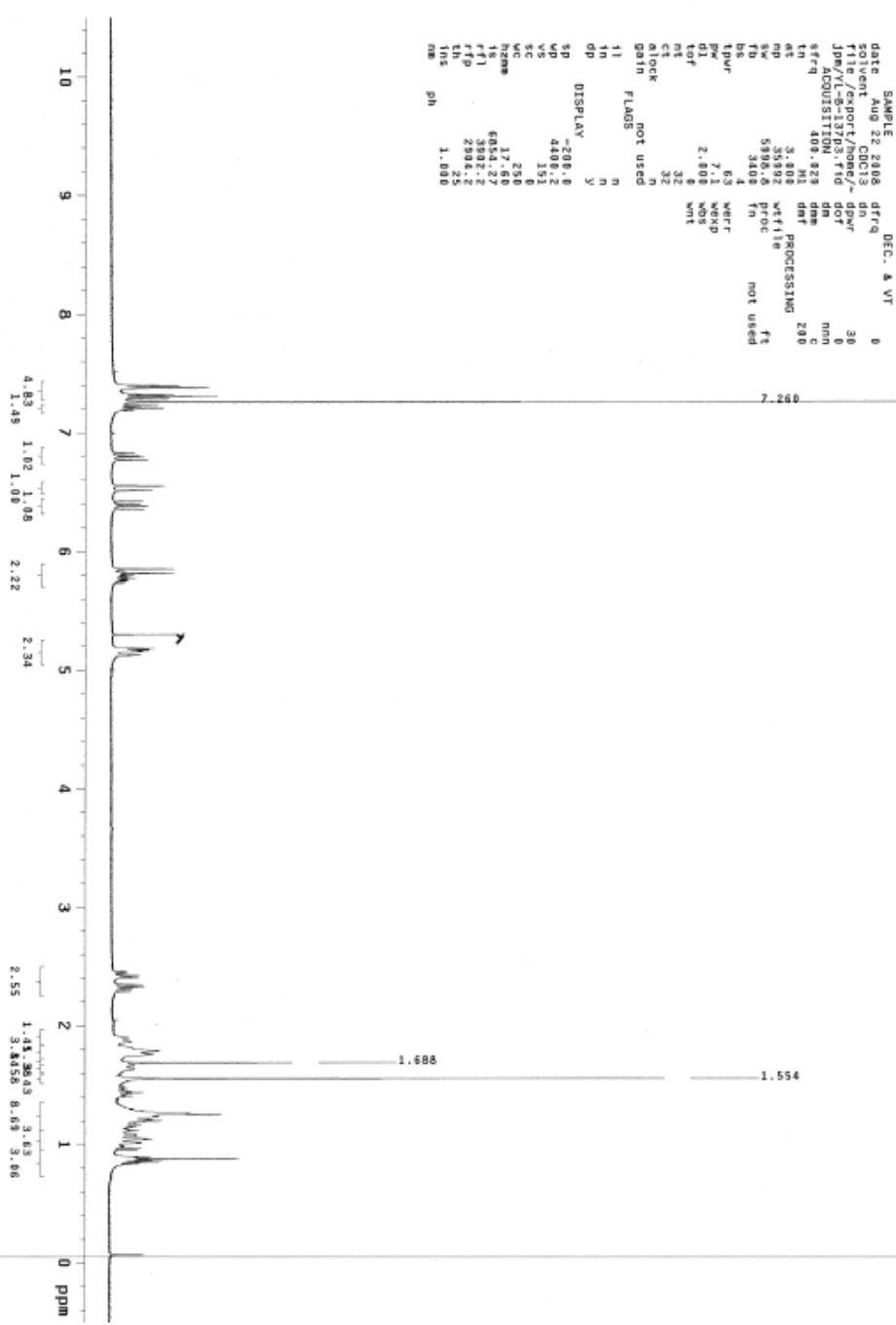


(5*E*,7*E*)-4-cyclohexyl-8-phenylocta-1,5,7-trien-4-ol.

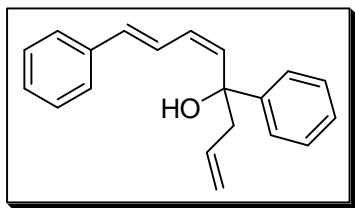
^1H NMR (400 MHz, CDCl_3): δ 7.40-7.19 (5H, m),
6.83-6.77 (1H, dd, $J=10.4, 15.6$ Hz), 6.55-6.51 (1H, d,

$J=15.6$ Hz), 6.42-6.36 (1H, dd, $J=10.4, 15.2$ Hz), 5.85-5.82 (1H, 15.2 Hz), 5.84-5.73 (1H, m), 5.8 1-5.13 (2H, m), 2.45-2.29 (2H, m), 1.69 (1H, s), 1.90-0.83 (11H, m); ^{13}C NMR (400 MHz, CDCl_3): δ 138.8, 137.6, 133.9, 131.8, 129.5, 128.8, 128.7, 127.5, 126.4, 119.6, 117.2, 76.5, 47.6, 43.6, 28.0, 27.0, 26.8; ; IR(neat): 3566 (br), 3077 (w), 3024 (w), 2927 (s), 2852 (s), 1637 (w), 1595 (w), 1495 (w), 1448 (m), 1347 (w), 1261 (w), 1158 (w), 1071 (w), 992 (s), 915 (m), 893 (w), 747 (s), 692 (s), 507 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{20}\text{H}_{25}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 265.19563 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 265.19433.

YL-8-137P3
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 sftq 100.429 dm 2
 tn 101 dat
 at 3.808 wffile
 mp 353.92 proc f1
 fw 339.26 tn
 bs 340.4 not used
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 pw 7.1 wexp
 tw 2.808 wos
 tof 4 wot
 nt 32
 ct 32
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 gain not used
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 sc 0
 wname 17.60
 is 6854.27
 rfi 3892.2
 rfp 2994.2
 tms 1.000
 me ph



95



(5Z,7E)-4,8-diphenylocta-1,5,7-trien-ol. ^1H NMR

(400 MHz, CDCl_3): δ 7.54-7.52 (2H, m), 7.38-7.33 (2H, m), 7.30-7.18 (7H, m), 6.45-6.41 (1H, d, $J=16.0$), 6.23

(1H, t, $J=12.0$ Hz), 5.90-5.87 (1H, d, $J=12.0$ Hz), 5.80-5.69 (1H, m), 5.23-5.19 (2H,

m), 2.74-2.73 (2H, d, $J=6.8$ Hz), 2.35 (1H, s); ^{13}C NMR (400 MHz, CDCl_3): δ 146.9

137.5 136.0 134.7 133.3 131.1 128.7 128.4 127.8 127.0 126.8 125.8 125.6 120.3 76.7

49.7; IR(neat): 3559 (br), 3075 (m) 3059 (m), 2919 (m), 2850 (w), 1634 (m), 1600

(m), 1492 (s), 1448 (s), 1414 (m), 1339 (m), 1276 (m), 1256 (w), 1049 (m), 1027 (s),

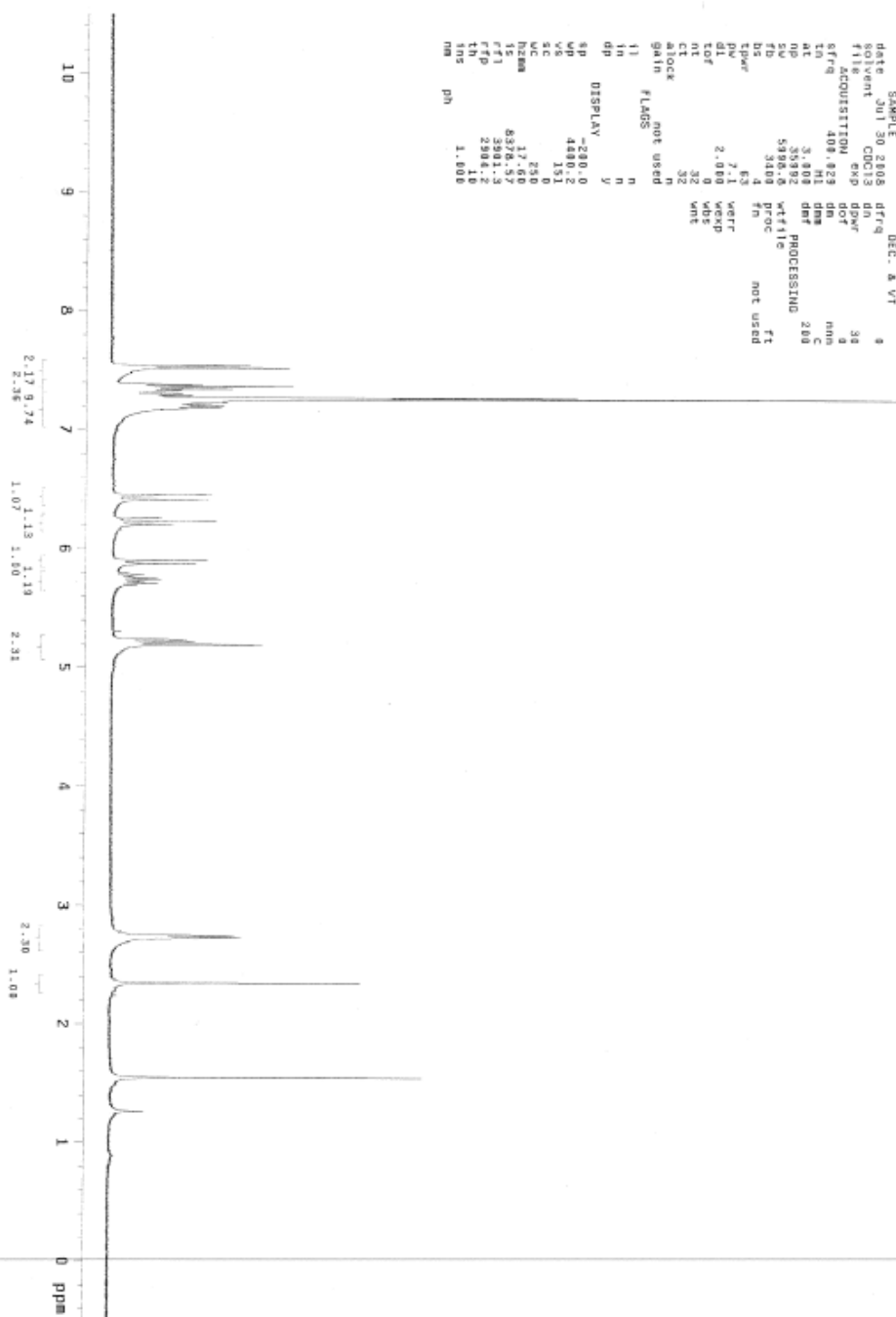
990 (s), 917 (s), 730 (s), 697 (s), 537 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{20}\text{H}_{19}$

$(\text{M}-\text{H}_2\text{O}+\text{H})^+$: 259.14868 Observed $(\text{M}-\text{H}_2\text{O}+\text{H})^+$: 259.14820.

VL-B-133P2
PULSE PROGRAM: s2pu1

exp1 stdh

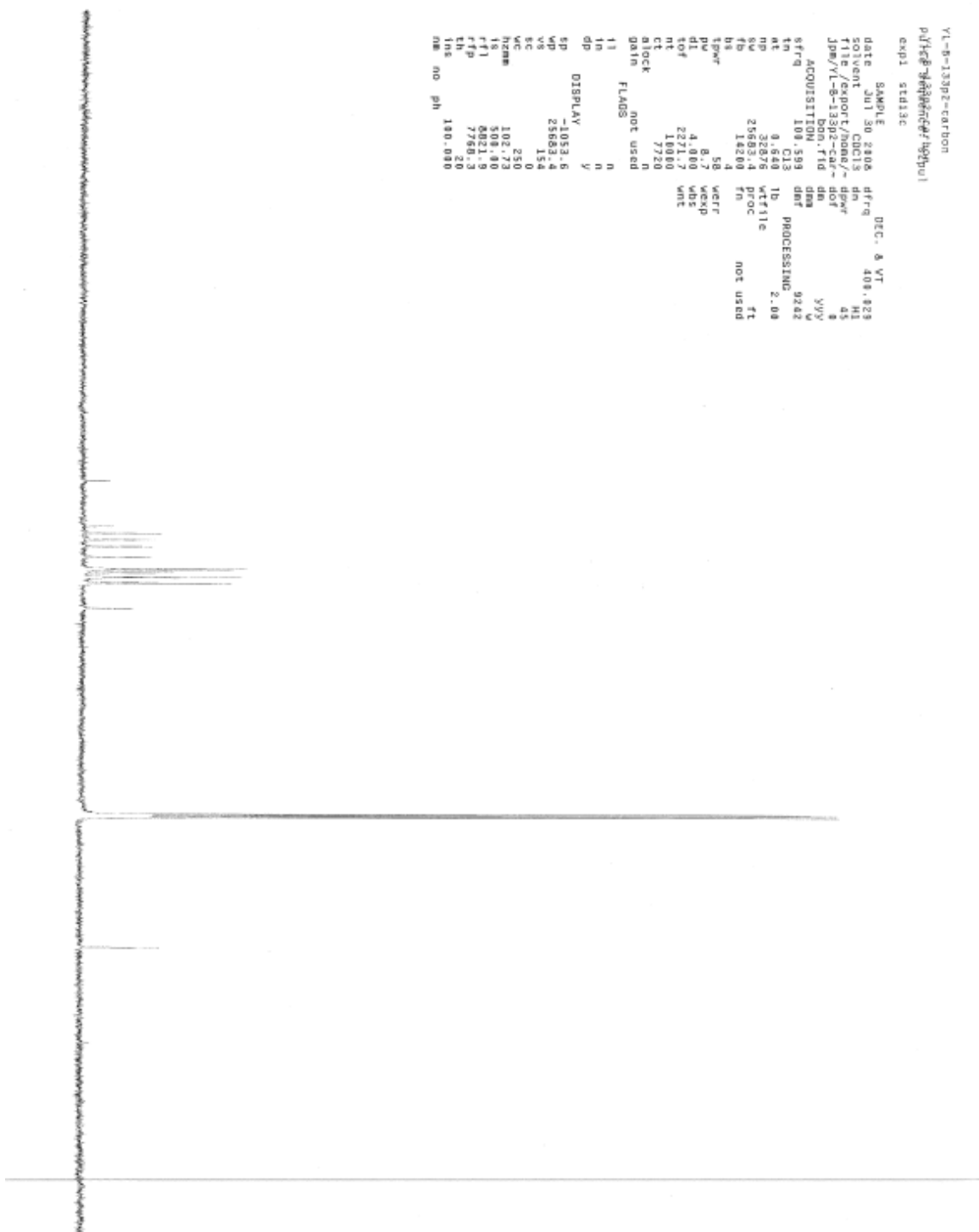
SAMPLE
date JUN 30 2006 dfrq DEC. A VT 9
solvent CDCl3 dn
file 133P2.d
ACQUISITION exp dpr 34
sfrq 400.423 dpr 34
in HI dmz nmz
at 3.408 dat 200
nd 359.92 v4 file
fd 3406 proc
b2 4 fm not used
tpr 63
pu 7.1 wefr
sv 2.00 wexp
tof 0
nt 32 wnt
ct 32
a lock n
gain not used
in flags n
in n
gp y
sp DISPLAY 200.0
wp 400.2
vs 151
sc 0
vsc 250
b2em 17.60
f71 8378.57
f72 3501.3
f73 2984.2
f74 171.8
f75 1.000
ms ph

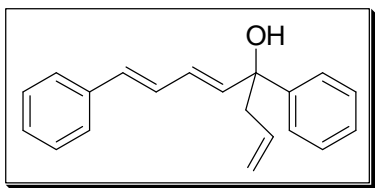


YL-B-133P2-carbon
 P:\133P2-carbon\YL-B-133P2-carbon

EXPI 201306

SAMPLE
 date Jul 30 2008 dfrg DEC. 8 VT
 solvent CDCl3 dn H1
 title /export/home/-dpar 45
 jpe/yl-b-133p2-car-dof 8
 bon.tid dm yyy
 wfrq ACQUISITION 100.593 dmw 9242
 tn 0.540 lb PROCESSING 2.00
 ap 32876 wfr11c fl
 bw 25683.4 proc not used
 fb 14200 fn
 bs 4
 bprf 50 wfrf
 pprf 87 wfrp
 dl 4.000 wbc
 tof 2271.7 wnt
 nt 10000
 ct 7720
 alock not used
 data not used
 f1 FLAS n
 f2 n
 dp n
 DISPLAY y
 sp -1053.6
 wp 25683.4
 wv 154
 wu 250
 wz 102.73
 hzmm 18 508.80
 f11 6021.9
 f1p 7768.3
 ch 20
 me no ph 100.000





(5E,7E)-4,8-diphenylocta-1,5,7-trien-4-ol. ^1H NMR

(400 MHz, CDCl_3): δ 7.49-7.47 (2H, m), 7.38-7.18

(8H, m), 6.82-6.75 (1H, dd, $J=10.4, 15.2$ Hz),

6.56-6.52 (1H, d, $J=16.0$ Hz), 6.47-6.41 (1H, dd, $J=11.2, 16.0$ Hz), 6.15-6.11 (1H, d,

$J=15.2$ Hz), 5.75-5.64 (1H, m), 5.23-5.17 (2H, m), 2.82-2.70 (2H, m), 2.25 (1H, s);

^{13}C NMR (400 MHz, CDCl_3): 145.5 139.5 137.4 133.3 133.0 129.2 128.8 128.5

127.7 127.1 126.5 125.6 125.4 120.3 75.8 47.3; IR (neat): 3564 (br), 3060 (w), 3025

(w), 2923 (s), 2852 (m), 1639 (w), 1597 (w), 1493 (w), 1447 (m), 1350 (w), 1250 (w),

1158 (w), 1072 (w), 991 (s), 917 (m), 747 (m), 699 (s) cm^{-1} ; LRMS (ESI+) Calc'd for

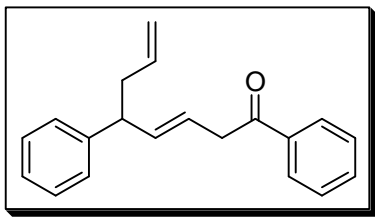
$\text{C}_{20}\text{H}_{19}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 259.14868 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 259.14865.

td1h |

Ph

VL-B-1433-carbon
 P:\k6B-3433\k6B1433p1
 exp5 10136

SAMPLE DEC. 3 VT
 date aug 28 2005 dfrq 400.024
 solvent CDCl3 dn H1
 title /export/home/~ dpr 45
 jpw/vl-b-1433-car- dof 0
 Don. file dn yyy
 ACQUISITION
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 f2 101.598 dmz v
 at 0.848 lb dmz PROCESSING 9242
 mp 32876 wifile 2.08
 sw 25683.4 proc ft
 fb 14200 fn not used
 bs 4
 vdw 52 woff
 pw 8.7 wexp
 dl 4.000 wbs
 tot 2271.7 wnt
 nt 10080
 ct 5456
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 f1307 n
 f1308 n
 f1309 n



(E)-1,5-diphenylocta-3,7-dien-1-one. ^1H NMR (400

MHz, CDCl_3): δ 7.96-7.89 (2H, m) 7.58-7.53 (1H, m),

7.48-7.41 (2H, m), 7.36-7.18 (5H, m), 5.83-5.65 (3H,

m), 5.07-4.93 (2H, m), 3.77-3.68 (2H, m), 3.42-3.37 (1H, m), 2.51-2.44 (2H, m); ^{13}C

NMR (400 MHz, CDCl_3): δ 198.3 (major) 197.9 (minor) 144.2 (major) 144.0 (minor)

137.7 136.8 (minor) 136.7 (major) 136.4 (minor) 136.1 (major) 133.2 128.7 128.6

128.5 127.8 (major) 127.6 (minor) 126.4 122.8 (major) 122.0 (minor) 116.6 (minor)

116.4 (major) 48.9 (major) 44.2 (minor) 42.7 (major) 41.4 (minor) 40.3 (major) 38.0

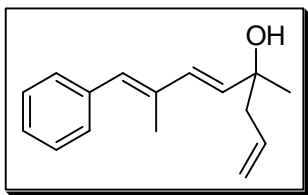
(minor); IR (neat): 3061 (w), 3026 (w), 2976 (w), 2922 (m), 2853 (w), 1684 (s), 1639

(w), 1597 (m), 1580 (w), 1492 (m), 1448 (m), 1401 (w), 1321 (m), 1273 (m), 1207 (s),

1180 (w), 1158 (w), 1073 (w), 969 (s), 912 (s), 844 (w), 754 (s), 697 (s), 690 (s), 663

(w), 579 (w), 535 (w) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{20}\text{H}_{21}\text{O}_1$ ($\text{M}+\text{H}$) $^+$: 277.15924

Observed ($\text{M}+\text{H}$) $^+$: 277.15951.



(5E,7E)-4,7-dimethyl-8-phenylocta-1,5,7-trien-4-ol. ^1H

NMR (400 MHz, CDCl_3): δ 7.36-7.20 (5H, m), 6.54 (1H, s), 6.46-6.42 (1H, d, $J=16.0$ Hz), 5.89-5.79 (1H, m),

5.88-5.84 (1H, d, $J=16.0$ Hz), 5.19-5.14 (2H, m), 2.41-2.31 (2H, m), 2.00 (3H, s),

1.73 (1H, s), 1.37 (3H, s); ^{13}C NMR (400 MHz, CDCl_3): δ 138.0 135.7 135.2 133.9

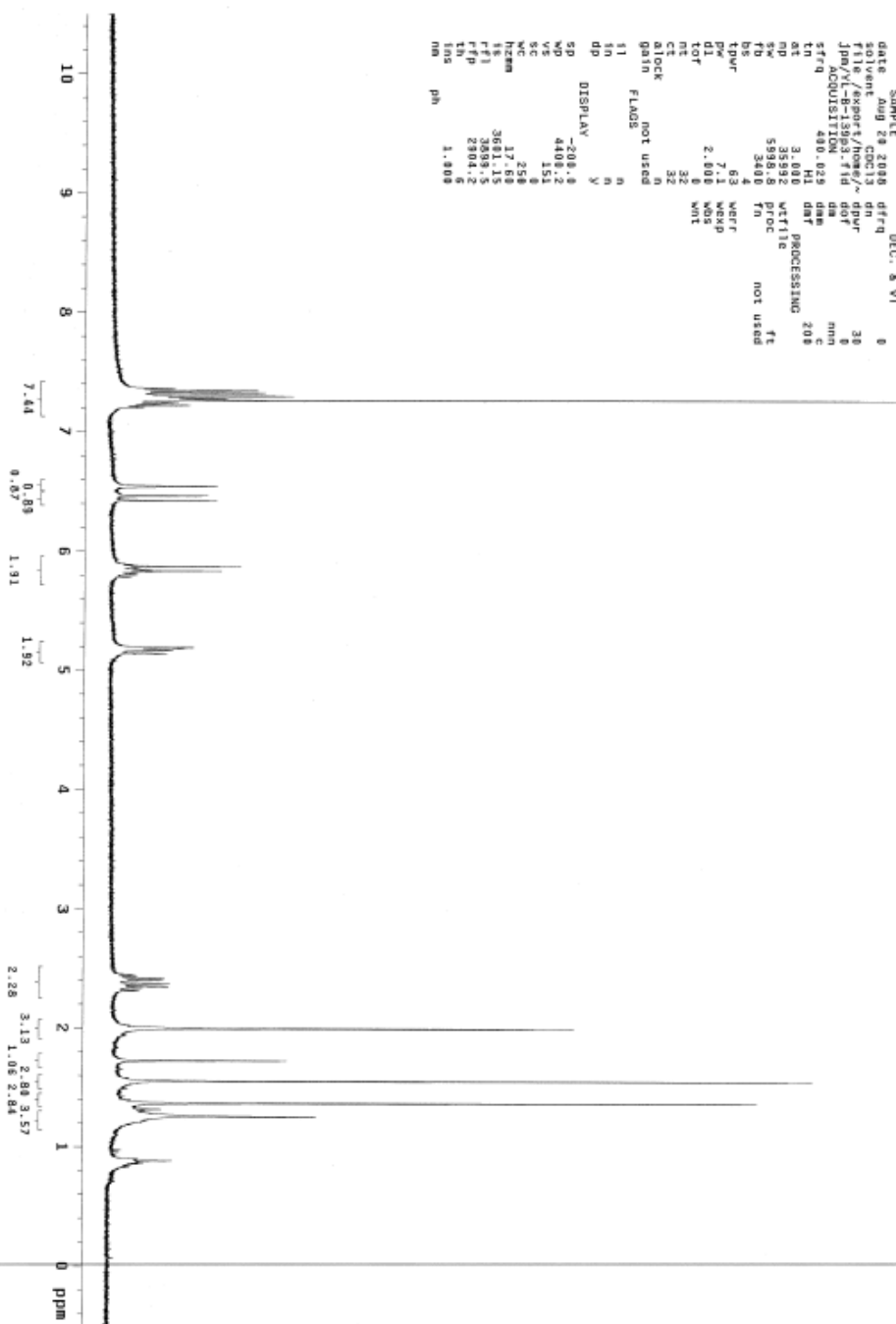
132.9 131.5 129.4 128.3 126.7 119.4 72.5 47.8 28.4 14.3; IR(neat): 3387 (br), 3377

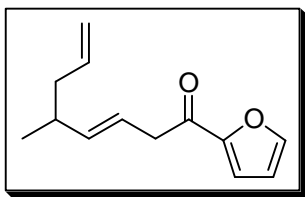
(w), 3022 (w), 2975 (m), 2925 (s), 2854 (w), 1640 (w), 1598 (w), 1492 (m), 1443 (s),

1370 (m), 1281 (m), 1236 (w), 968 (s), 916 (s), 825 (m), 747 (s), 699 (s), 508 (w) cm^{-1} ;

LRMS (ESI+) Calc'd for $\text{C}_{16}\text{H}_{19}$ ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$: 211.14868 Observed ($\text{M}-\text{H}_2\text{O}+\text{H}$) $^+$:

211.14915.

[illegible]

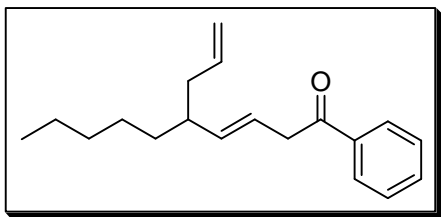


^1H NMR (400 MHz, CDCl_3): δ 7.59-7.58 (1H, m), 7.20-7.19 (1H, m), 6.54-6.53 (1H, m), 5.77-5.70 (1H, m), 5.65-5.52 (2H, m), 5.00-4.94 (2H, m), 3.54-3.52 (2H, d, $J=5.6$ Hz), 2.30-2.19 (1H, m), 2.13-1.97 (2H, m), 1.00-0.98 (3H, d, $J=6.8$ Hz); ^{13}C NMR (400 MHz, CDCl_3): δ 187.6 152.6 146.5 140.5 (major) 139.4 (minor) 137.1 120.3 (major) 119.5 (minor) 117.5 (major) 117.3 (minor) 116.0 112.4 42.8 (major) 41.7 (minor) 41.4 (major) 37.8 (minor) 36.7 (major) 20.7 (minor) 20.0 (major); IR(neat): 3132 (w), 3076 (w), 2960 (m), 2924 (m), 2871 (w), 1677 (s), 1640 (w), 1568 (m), 1467 (s), 1439 (w), 1393 (m), 1324 (w), 1290 (m), 1237 (m), 1157 (m), 1084 (m), 1014 (m), 993 (m), 972 (m), 913 (s), 883 (s), 761 (s), 640 (w), 595 (m) cm^{-1} ; LRMS (ESI+) Calc'd for $\text{C}_{13}\text{H}_{17}\text{O}_2$ ($\text{M}+\text{H}_2\text{O}+\text{H}$) $^+$: 205.12285 Observed ($\text{M}+\text{H}_2\text{O}+\text{H}$) $^+$: 205.12311.

exp1 std13c

nn no ph





(E)-5-allyl-1-phenyldec-3-en-1-one. ^1H NMR

(400 MHz, CDCl_3): δ 7.98-7.95 (2H, m),

7.58-7.43 (3H, m), 5.78-5.69 (1H, m), 5.57-5.61

(1H, m), 5.41-5.34 (1H, m), 4.97-4.92 (2H, m), 3.74-3.69 (2H, m), 2.12-1.99 (1H+2H,

m), 1.36-1.20 (8H, m), 0.86-0.83 (3H, m); ^{13}C NMR (400 MHz, CDCl_3): δ 198.7

139.0 (major) 137.8 (minor) 137.2 (major) 136.9 (minor) 133.2 (minor) 133.1 (major)

128.7 128.6 128.5 122.5 (major) 121.4 (minor) 116.0 (minor) 115.8 (major) 42.9

(minor) 42.8 (major) 40.2(minor) 39.9 (major) 38.3 (minor) 38.1 (major) 35.3

(minor) 34.6 (major) 32.3 (minor) 32.2 (major) 27.2 (minor) 27.0 (major) 22.9 14.3;

IR(neat): 3073 (w), 2956 (m), 2925 (s), 2856 (m), 1686 (s), 1639 (w), 1598 (w), 1581

(w), 1448 (m), 1331 (w), 1274 (m), 1207 (s), 1180 (m), 1073 (w), 991.5 (m), 970 (m),

911 (m), 750 (m), 732 (w), 690 (s), 663 (w), 597 (w), 574 (w) cm^{-1} ; LRMS (ESI+)

Calc'd for $\text{C}_{19}\text{H}_{27}\text{O}_1$ ($\text{M}+\text{H}$) $^+$: 271.20619 Observed ($\text{M}+\text{H}$) $^+$: 271.20650.

